APPENDIXES

TO THE

REPORT OF THE CHIEF OF ENGINEERS,

UNITED STATES ARMY.

(CONTINUED.)

ANNUAL REPORT

OF THE

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FOR

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APPENDIXES

TO THE

REPORT OF THE CHIEF OF ENGINEERS,

UNITED STATES ARMY.

(CONTINUED.)

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REPORTS OF THE MISSISSIPPI RIVER COMMISSION.

W W 1.

REPORT FOR 1884.

WAR DEPARTMENT,
Washington City, January 5, 1885.

The Secretary of War has the honor to transmit to the House of Representatives the annual report of the Mississippi River Commission for 1884.

The estimate, $100,000, of the Commission for salaries, traveling expenses, &c., for the fiscal year 1886 will be found on page 204 of the Book of Estimates for 1885–'86 (House Ex. Doc. No. 5, Forty-eighth Congress, first session), and the three items, $500,000, $1,000,000, and $7,000,000, for continuing the improvement of the river, are included (page 168 of said document) in the amount, as reported by the Chief of Engineers, which can be profitably expended in the next fiscal year.

ROBERT T. LINCOLN,
Secretary of War.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

REPORT.

THE MISSISSIPPI RIVER COMMISSION,
PRESIDENT'S OFFICE,
New York, December 19, 1884.

SIR: The Mississippi River Commission have the honor to submit the following report, embracing the subjects and subdivisions specified below, to wit:

1. Progress of surveys and examinations since December 1, 1883.
2. Construction.
3. Remarks on the subject of levees and outlets.
4. General discussion of the problem of the rectification of the Red and Atchafalaya rivers.
5. Legislation.

6. Financial statements and estimates of funds for the fiscal year ending June 30, 1886, for "surveys and expenses of the Commission, and for improving Mississippi River."

PROGRESS OF SURVEYS AND EXAMINATIONS.

The surveys and examinations undertaken in pursuance of the requirements of the third section of the act under which the Commission was organized have been continued.

In the last annual report progress in this branch of work was noted to December 1, 1883. From that date to December 1, 1884, work has been accomplished in field and office as follows:

Gauges.—Daily readings have been taken and displayed at all the stations previously established. New stations have been occupied on the principal tributaries, and continuous records obtained from the dates of establishment.

These gauges are: Paducah, on the Ohio, June, 1884; Wittsburg, on the Saint Francis, June, 1884; Clarendon, on the White, July, 1884; Yazoo City, on the Yazoo, July, 1884.

The Commission now maintains twenty gauges on the Mississippi and tributaries. Since the inauguration of the present inspection service, mentioned in the last report, the breaks in the records of these gauges have been few and brief.

The miscellaneous work performed in connection with the gauge inspection is detailed in the report of the secretary of the Commission.

The only violent change in the regimen of the river has been a cut-off, which occurred about May 10, 1884, through a narrow neck nearly midway between Vicksburg and Natchez. The channel was shortened about 12 miles. A survey was obtained within a few days after the event, and two have been made since. It is proposed to continue these examinations at, above, and below the cut-off, to determine as far as possible its immediate and ultimate effects upon the channel in its vicinity.

Precise levels.—No field work has been done during the year. The final reduction of the portion of the line between the Mississippi River and Lake Michigan has been completed.

Final topography and hydrography—Has been completed from Trotter's Landing to Saint Louis Landing, 45 miles; from Plum Point to Randolph Point, 46 miles; from Donaldson's Point to Caruthersville, 50 miles; and from Grand Tower to Devil's Island, 27 miles; making a total of 168 miles surveyed during the year. The survey of the river, with marginal topography, is now complete from Cairo to the Gulf.

Detail charts (scale one ten-thousandth have been finished from Greenville to Lake Providence, and from Waterproof to Donaldsonville, covering 222.4 miles of river. The charts from Cairo to New Madrid, Caruthersville to Memphis, and Commerce to Saint Louis Landing, lack only the topographical signs.

The publication of a series of charts on the scale of 1:20000 has been decided upon and material for twenty of them and in part for thirteen more has been prepared.

Work on the preliminary chart (1 inch to a mile) has been continued. Five sheets, extending from Rodney to Donaldsonville, have been drawn, and five sheets, extending from the foot of Island 97 to Jackson's Point, published. Three sheets are now ready for the printer, and two more, completing the series, will be ready early in January; and the entire series will be in print by the first of March.

Miscellaneous.—Observations of the flood escape through crevasses

were again made at the last high water. The collection of reliable high-water marks has been continued.

Especial attention has been given this year to obtaining correct data as to the depths on bad bars at low water.

Experimental work at the discharge stations of 1882 has been reduced.

A financial statement and an itemized statement of expenditures from the appropriation act of March 3, 1883, appear below.

The following papers relating to the work of surveys and examinations are submitted as appendices to this report:

Appendix A.—Annual report of the secretary of the Commission.

Appendix B.—Final results of precise leveling from Fulton to Chicago.

Appendix C.—Reports upon the field work of topography and hydrography.

Appendix D.—Results of experimental work at discharge stations.

CONSTRUCTION.

At the date of the last annual report, December 21, 1883, operations under this head were drawing to a close, the funds in the hands of the Commission being exhausted. Owing to their apprehension of damage to unfinished work during the high-water season, then near at hand, the Commission recommended to Congress an immediate appropriation of $1,000,000 to enable the work to continue during the balance of the fiscal year. Congress acted on this suggestion, and the sum asked for was appropriated by act approved January 19, 1884. Unfortunately, the relief came too late, as the river began rising rapidly in the latter part of December and remained at a very high stage, which finally culminated in the latter part of February in a flood of about the same magnitude as those of the two preceding years. The river remained high for a long period, and but little work could be done before July. The damage done to the works was, on the whole, less than might have been anticipated. The pile-dikes sustained much less injury than had been the case in former years, due no doubt to the improved methods of construction which had been adopted, but the revetment work, much of which had been left in an incomplete state, suffered severely.

During the present season all damage has been repaired, the systems of pile-dikes have been strengthened and extended, and much revetment work of improved character has been carried on. The funds available will be about exhausted January 1, 1885, and although it is hoped and expected that by that time the season's work will be left in much better shape than heretofore, yet much more satisfactory results might have been secured had the appropriation for these works been more liberal. The caving banks within the reaches under improvement are very extensive, and the means at the disposal of the Commission have not hitherto been adequate to complete their protection. The caving of these banks has given serious trouble, necessitated many changes of plan, and in some instances has jeopardized the whole system of contraction works put in to control and deepen the navigation channel. This danger will continue till these banks are secured, which will require considerable expenditure and should be completed in one season if possible.

The marked improvement of low-water depth where works are being carried on, alluded to in last year's report, was again exemplified at the recent low water. Wherever the contraction works had been even approximately completed the depths were nearly double those found on the

unimproved portions of the river in their vicinity. It seems as if this fact should settle all doubts as to the possibility of so improving the navigation of the river by the methods adopted by the Commission as to meet any reasonable requirement. The minor difficulties incident to the inception of any new work are fast disappearing as experience is acquired, and all that now seems necessary to make the work successful is that funds shall be supplied liberally and promptly.

During the low-water season of 1883 not more than 6 feet of water was found through the New Madrid and Memphis reaches, which lie, respectively, above and below that of Plum Point. The case this year was but little better. It would seem, therefore, advisable to extend the work to these reaches as soon as possible, as such a course would open to an improved navigation about 250 miles of river from Cairo down, or about one-fourth of the distance to New Orleans, and nearly one-half the total distance which requires extensive improvement. That such a result would be of great value to navigation cannot be doubted. The Commission have prepared plans for beginning work on these reaches, and will take them in hand as soon as the funds placed at their disposal will justify such action. They also deem it essential to the success of the work already done, and a necessary part of their plan of improvement, that the revetment of banks which are caving with sufficient rapidity to endanger or embarrass navigation, should be at once undertaken and carried forward systematically beginning at Cairo and progressing down-stream, precedence in time being given to those places where the caving is most rapid or injurious. Throughout the portions of river lying between the reaches of bad navigation are found many long stretches where navigation is now good, and which only need work of this character to keep it so, while at other points shoals exist which would probably disappear or become less troublesome if the banks were held and the river allowed to contract and deepen by natural agencies. The fixation of the channel is of the utmost importance in the plan of improvement contemplated by the Commission, as otherwise changes may occur from the caving of the banks which will destroy or render useless costly works of improvement, and, by causing fresh shoals where navigation is now good, render an indefinite extension of the work necessary. This work is conservative in its nature, and cannot supersede the work already begun or projected for the shoal portions of the river; but it is an important adjunct, and, as much time will be required for its execution, there should be no delay in beginning it. The Commission have provided for initiating this work between Cairo and Memphis in the estimate which accompanies this report.

By the terms of the last river and harbor act the Commission were directed to take charge of the improvement of the Mississippi River between the mouth of the Ohio and the Des Moines Rapids, upon which work has for many years been in progress under the Engineer Department, U. S. A. Projects for the season's operations were prepared by the officers in charge of the works, and, having received the approval of the Commission, are now in process of execution. Estimates for continuing these works are submitted.

The names of a large number of harbors were inserted in the river and harbor bill, with a view to their improvement; but as the amount appropriated was far short of the estimates of the Commission, they did not feel justified in taking up this work except at Memphis, where the act specified the amount to be expended, and at Vicksburg, where repairs were needed to work already done. The Commission have, how-

ever, prepared separate estimates for such work at these places as seems necessary to accomplish the objects proposed, and these estimates are submitted to Congress for such action as they may deem proper, it being the desire of the Commission, if Congress decides that any or all of this work be undertaken, that they will specify the localities and the amount to be expended at each.

WORKS ABOVE CAIRO.

(Des Moines Rapids to mouth Illinois River, 161 miles in length. Officer in charge, Maj. A. Mackenzie, Corps of Engineers, U. S. A., to September 1, 1884. Since that date, Capt. E. H. Ruffner, Corps of Engineers, U. S. A.)

HEADQUARTERS, QUINCY, ILL.

The general plan upon which work in this district is in progress consists in closing all side channels by low dams, usually of brush and stone; in contracting the width of the river, where excessive, by spur dikes of similar construction to the dams, and in protecting by brush mattresses covered with stone such banks as are subject to erosion. The object sought is to contract the low-water channel to a uniform width and thereby increase its depth to about 5 feet at low water. This work has been in progress for several years and the general results have been good.

Since this work came under the direction of the Commission, the dams opposite Quincy have been raised and repaired; the shore of Buffalo Island, below the Louisiana Bridge, has been revetted and the dam opposite the foot of the island has been repaired. At the dam between Brockaw Island and the Illinois shore the foundation for the dam has been laid; the shore protection and the dam itself are in progress. An experimental dam composed of piles and sheet piling has been built between the Illinois shore and Island No. 421, opposite La Grange, Mo. There is also in progress a wing-dam half way between Canton and La Grange, shore protection at Bolter's Island, and a dam from this island to the adjacent tow-head. A contract has also been made for dredging Quincy Bay. All of this work has been much delayed and impeded by the high stage of water which has prevailed during the fall season.

Work must soon close on the advent of cold weather, but will be resumed in the spring and prosecuted to the extent of the available funds.

For details of work in this district see Report of Capt. E. H. Ruffner, Corps of Engineers, U. S. A., Appendix K.

(Mouth of Illinois to mouth of the Ohio, 241 miles in length. Officer in charge, Maj. O. H. Ernst, Corps of Engineers, U. S. A.)

HEADQUARTERS, SAINT LOUIS, MO.

In this district also the work has been in progress for several years, under the Engineer Department, U. S. A.

Above the city of Saint Louis, the only point where work is now in progress is at Alton Harbor, where a dike, built in former years to improve the depth of water at the landing, is being repaired and raised to a uniform grade of 14 feet above low water. On October 1, 1,680 feet had been finished, and the balance was well advanced, though work had been stopped by high water. It is expected that the work will be completed in the spring.

Below Saint Louis begins the general work of improvement ultimately intended to extend out to Cairo. The general plan of this work is similar to that adopted by the Commission for the Lower River, and the methods employed are also similar. The plan consists essentially in narrowing the river to an approximately uniform width of 2,500 feet,

by building up new banks and reclaiming portions of the river bed by various silt-arresting devices. All banks exposed to erosion are to be protected by mattress revetment covered with stone. The plan thus outlined contemplates an ultimate improvement in channel depth that will give 8 feet between Cairo and Saint Louis at low water, and has been perfectly successful so far as carried out.

Since this work passed under the charge of the Commission, but little has been accomplished, owing to the late date at which the necessary preparations were completed. It will be pushed henceforth as rapidly as possible.

At *Arsenal Island*, the head of the island and the west side have been revetted for a distance of 1,283 feet. This work secures a stone revetment, previously placed there to protect the upper bank. The new work extends 300 feet above the head of the old work, and the upper bank over this extension has been riprapped, as also 100 feet on the east side of the island.

At *Horsetail*, on the west side, the shore protection of stone has been raised from 6 feet to 21 feet above low water for a length of 1,150 feet. On the Illinois side two new hurdles, Nos. 27½ and 29½, have been extended an aggregate length of 1,415 feet, and nearly completed, while another new hurdle, No. 31, has been begun. There was not less than 9 feet over this bar at the last low water.

At *Twin Hollows*, on the west side, repairs to the primary hurdle and to secondary hurdles Nos. 1, 4, and 5 were begun and partly completed. This work has given very good results, there having been not less than 9 feet in the channel at low water this season. The works require further extension, which can now be undertaken. At *Twin Hollows*, on the east side, the revetment of the Illinois shore is being extended. The mattress will be 120 feet wide from low-water mark and extend 990 feet along the bank.

At *Pulltight* the wattling of hurdle No. 5 has been completed, and hurdle No. 4, 1,770 feet long, has been begun and partly finished.

At *Jim Smith's* work has been confined to the reconstruction of the old hurdles and to putting new ones in the intervals. In all there are 9 hurdles, which are well advanced. The least depth at this point was 7½ feet.

At *Cairo*, according to the requirements of the river and harbor bill, a revetment is being constructed back of the town. By the terms of the act this is to extend down-stream from the lower end of the revetment constructed in former years by the Government, and $50,000 is allotted for the purpose. This work is now in progress. The mattress revetment, 120 feet wide, extends around and between the stone dikes put in by the Cairo Land Company, and will be continued down-stream as far as the funds allotted will allow.

For details of work in this district, see report of Maj. O. H. Ernst, Corps of Engineers, U. S. A., Appendix L.

WORKS BELOW CAIRO.

FIRST DISTRICT.

(Cairo to foot of Island No. 40, 220 miles in length. Officer in charge, Capt. J. G. D. Knight, Corps of Engineers, U. S. A.)

HEADQUARTERS, CAIRO, ILL.

This district includes the New Madrid Reach, extending from the head of Island No. 8, 42 miles below Cairo, to the foot of Island No. 14,

a distance of 60 miles; the Plum Point Reach, extending from the head of Island No. 26, 147 miles below Cairo, to the head of Island No. 35, a distance of 40 miles, and the harbors of Columbus and Hickman, Ky

NEW MADRID REACH.

No work has been done on this reach beyond preparing a plan for its improvement, which it is hoped may be soon put in execution, as the shoals have given much trouble during the last two low-water seasons.

PLUM POINT REACH.

No modification has been made in the general project as described in our last annual report, and work during the season has been in continuation of that project.

The revetment at Ashport, Tenn., has not been extended during the season; the old work is still intact.

The system of contraction works at Gold Dust Point, designed to close the chutes behind Elmot Bar and Island No. 30, was not entirely completed at the date of last report, and when the high water occurred there were gaps in the main dike and all the cross-dikes except the lower one, No. 5. Through these gaps the rising river poured with great velocity, carrying masses of drift, which finally proved too heavy for dike No. 5. This dike was breached, and some of the others were more or less damaged, the main dike being broken up for a length of 400 feet. Subsequently these dikes were repaired and strengthened. Those gaps which could not be closed were mattressed to prevent scour, and the whole system has been prepared, as well as possible, to resist the attacks of another flood. The deposit obtained by this system of dikes has been very great, some 3,000,000 cubic yards in all. In many places this fill extends 30 feet above low water, and recent surveys show that at low water the chute below dike No. 5 would be dry.

Opposite to the Gold Dust dikes the right bank, from Mill Bayou to Elmot's Landing, is caving badly. A revetment, 175 feet wide, for its protection, has been begun at Fletcher's Field, and a length of 4,930 feet has been built, besides 800 feet of revetment of less width. The upper bank has been graded and revetted for a length of 2,000 feet. Some difficulty has been met with here from seepage water from the bank, which has a tendency to wash down the upper portion of the revetment.

Of the system of works designed to close Osceola Chute, and to hold the tow-head, dikes Nos. 1 and 2 are in good condition. Behind No. 1 the chute is now dry at a 10-foot stage, and a growth of willows has started over a large portion of the old river-bed. A gap in dike No. 3 has been closed and general repairs made. This dike is now in good condition. The revetment on the upper tow-head, destroyed in 1882 and 1883, has not been replaced. On the lower tow-head there was, at date of last report, 2,663 feet of revetment 150 feet wide; the upper bank was unprotected. This work was not resumed till August, 1884, when it was found necessary to build a narrow mat, 1,337 feet long, at the head of the work, to connect the old revetment with the shore. The upper bank has now been graded and 872 feet revetted with brush. It is expected to complete this work, as far as the sub-aqueous mat extends, before operations close this winter. Osceola dike, No. 4, has been built this season. It was finally located below the foot of Osceola Bar to check a tendency to cut through into Bullerton Chute. This ob-

ject was successfully accomplished, though much difficulty was experienced in the construction of the dike, which is 2,450 feet long. During the time it was building, the Arkansas shore caved badly and the channel deepened to 50 feet; an offset in the dike was needed to pass this deep place. Since its completion large masses of drift have accumulated above the dike and a heavy fill has taken place in its neighborhood; this amounts to 15 feet in depth 100 feet below the dike.

At Bullerton Tow-head at date of the last annual report the revetment of the river side lacked 500 feet of mattress, 2,700 feet of upper-bank protection, and much stone. This work has since been completed, and all weak places repaired. There have been several slides, due to seep water returning to the river, and attempts are being made to prevent this action by the construction of broken-stone drains to collect and carry off this water. The low-water channel having finally left Bullerton Chute, dike No. 1, across this chute, is about to be closed, and No. 2 dike has been begun. Both these dikes will be completed before the season closes.

The dikes under Plum Point, designed to contract the channel between Bullerton Tow-head and Yankee Bar, have been extended 11,565 feet during the year, and now aggregate 15,010 feet in length; 1,000 feet more in length is required to complete the portion now authorized, after which no further extension will be made till all danger is over of the channel returning to Bullerton Chute.

At Craighead Point the revetment of the right bank has been begun, but not much progress made; 1,100 feet of mattress has been sunk just below the foot of Bullerton Tow-head. Its construction was attended with much difficulty, owing to the strength of the current encountered.

During the low water of this season there were five channels through Bullerton Bar, two of which led into Bullerton Chute, and were cut off by the construction of Osceola Dike, No. 4, and the dikes in the chute itself; one channel ran along Plum Point and Yankee Bar, and was cut off by the extension of the Plum Point dikes; the other two were located, one against the river side of Bullerton Tow-head; the other in the middle of the river. Much trouble was experienced at first from this great dispersion of the water, but as the contraction works were advanced and began to act, the Bullerton Tow-head Channel finally became the main one and gave 12 feet of water at the lowest stage reached. More or less trouble must be expected at this place till the contraction works can receive their full development and have time to act. The effect exerted by them in their present incomplete state leaves no doubt, however, as to the ultimate success of the work.

Much revetment work remains to be done on this reach, both between Ashport and Craighead Point, and also in the vicinity of Island No. 26, where serious changes are threatened. The dike work is nearly completed, and will mainly need watching and repair.

COLUMBUS, KY.

This is one of the harbors named in the river and harbor bill. The trouble here lies in the caving of the bank in front of the town. It is thought that the protection of 3,000 feet of bank will be required, which, at $20 per foot, will cost $60,000. To this must be added $20,000 for plant, making a total estimate of $80,000.

HICKMAN, KY.

This harbor is also named in the river and harbor bill, and the trouble is the same as at Columbus, Ky. It is thought that 12,000 feet of bank

will require protection, which, at $20 a foot, will cost $240,000. To this must be added $30,000 for plant; making a total estimate of $270,000.

For details of work in this district, see report of Capt. J. G. D. Knight, Corps of Engineers, U. S. A., Appendix F.

SECOND DISTRICT.

(Foot of Island No. 40 to mouth of White River, 180 miles in length. Officer in charge, Maj. A. M. Miller, Corps of Engineers, U. S. A., till September 1, 1884; since that date, Capt. C. B. Sears, Corps of Engineers, U. S. A., temporarily.)

HEADQUARTERS, MEMPHIS, TENN.

In this district are included the Memphis and Helena reaches, the first extending from the foot of Island No. 40, 220 miles from Cairo, to Scanlan's Landing, a distance of 27 miles, and the second extending from Commerce Cut-off, 270 miles from Cairo to Friar's Point, Mississippi, a distance of 55 miles.

The first reach embraces Memphis Harbor.

MEMPHIS HARBOR.

The revetment in front of the city, which has been built at various periods since 1878, and which has heretofore given much satisfaction, gave way during the flood of 1884 at several points, and caused the destruction of much valuable property. Much alarm was felt in the city, and Congress directed the expenditure of $200,000 in renewing the protection. Surveys have shown that the trouble was due to the caving in Hopefield Bend, and the great growth of the bar opposite the town, upwards of 750 feet in two years. Both these influences combined to push the deep water against the town front and to cause a severe scour of the river bed. This undermined the revetment and caused its failure. As soon as possible orders were given to start the work, using mattresses 300 feet wide instead of 120 feet, the width of the old ones. The first attempt to sink these wide mattresses failed, the mattresses pulling to pieces under the heavy strain; later reports, however, indicate success. Meanwhile a narrow mattress, 150 feet wide, has been carried from a point 500 feet above Wolf River, across that stream and along the city front, a total distance of 3,925 feet. The wide mattress will be laid on top of this narrow one. The upper bank is being graded and covered with stone.

This revetment must be carried along the whole city front to insure its safety, and an estimate of $75,000 for its completion accompanies this report.

MEMPHIS REACH.

Work on the reach has been confined to the revetment of Hopefield Bend, immediately above the city of Memphis. At the date of our last report 6,700 feet of mattress was down, and 4,100 feet of upper bank protection completed. Before the high water set in this had been increased to 10,400 feet of mattress, made and sunk, and 5,700 feet of upper bank protection. The mattresses were 140 feet wide. During the flood the bank caved badly, where the upper bank had not been secured, and this portion of the revetment was lost. The remainder sustained some damage from the seepage of water from the bank after the subsidence of the flood. It is hoped to repair and complete this work during the coming season.

Plans have been prepared for the improvement of this reach, which the Commission desire to undertake as soon as funds will allow, the bars in the immediate neighborhood of Memphis having been very troublesome both in 1883 and 1884.

HELENA REACH.

No work has been done on this reach during the season.

For details of work in this district see report of Capt. C. B. Sears, Corps of Engineers, U. S. A., Appendix G.

THIRD DISTRICT.

(Mouth of White River to Warrenton, 220 miles in length. Officer in charge, Capt. W. L. Marshall, Corps of Engineers, U. S. A., to April 21, 1884; since that date, Capt. C. B. Sears, Corps of Engineers, U. S. A.)

HEADQUARTERS, MEMPHIS, TENN.

In this district are included the Choctaw Reach, extending from Cork's Point, Arkansas, 422 miles below Cairo, to Arkansas City, Ark., a distance of 31 miles; the Lake Providence Reach, extending from Carolina Landing, 530 miles below Cairo, to the foot of Island No. 95, a distance of 35 miles, and the improvement of the harbors of Greenville and Vicksburg, Miss.

CHOCTAW REACH.

No work has been done on this reach during the season.

LAKE PROVIDENCE REACH.

The work on this reach during the past year has been in continuation of that outlined in our last report, the only new work being the Cottonwood system of dikes.

In Louisiana Bend two detached pieces of revetment, the upper 1,600 feet and the lower 2,000 feet long, had been built at the date of our last report. Of these, the upper piece is safe, the lower one was flanked by the river, and now lies on the bottom. The work has been vigorously pushed this fall, 14,000 feet having been completed, including the grading and protection of the upper bank. The holding of this bank is of the greatest importance, as its recession throws the whole force of the current against the Duncansby system of dikes on the opposite side of the river. The river is still encroaching on these works, and will continue to do so until the caving above is stopped.

Work on the Duncansby system has been confined to repairs of dikes that had been damaged during the flood, and to the completion of the dike on range No. 36.

So far, these works, which are designed to keep the river out of Skipwith's Chute, have successfully accomplished this object, and the silting up of the chute is steadily progressing.

In the Mayersville system the Cottonwood system of dikes has been built this season. They were designed to close a channel which was developing along the Louisiana shore, near Cottonwood Point. This object has been successfully accomplished, and the dikes are in good order. Their total length is 8,527 feet.

In Mayersville chute the heavy five-row cross-dike was breached for a length of 125 feet by the pressure of drift. This gap has been closed and more cross-dikes are being constructed farther down the chute.

The caving of the Mississippi shore above the head of the chute and the general movement of the deep water towards Mayersville Island, has caused the destruction of most of the longitudinal dike across the head of the chute. This, however, is not of much importance, as the dikes in the chute are sufficient for the purpose intended.

The revetment on the outside of Mayersville Island has been kept up, though with much difficulty on account of the sandy character of the soil. It will have to be held by constant work till the river outside has adjusted itself to the new conditions.

The Baleshed system of dikes is in good order and has given excellent results. Foot-mats were put in at the head of the system last winter, and a high dike has been constructed behind the original low longitudinal dike, between cross-dikes 1 and 6. Repairs have also been made to cross-dikes 3 and 4, and to the main dike below No. 6. Two or more additional cross-dikes are required in Baleshed chute to break up the fall, which is now excessive. A cross-dike 2,000 feet long has been built above Stack Island, and the main dike, from this cross-dike to the head of the island, has been strengthened. Very great deposits have been induced by this system of dikes, and the head of the work is now dry at a half stage.

The Hopewell system of dikes has not required attention during the year.

The excellent low-water depths reported last year throughout this reach prevailed again during the recent low water; 15 feet was the least depth found on the reach, which was 6 or 7 feet more than was available for 40 miles above or below.

VICKSBURG HARBOR.

No work was done during the year on the inner harbor and none is proposed. Recent surveys show that no changes of importance have occurred.

At Delta Point, on the opposite side of the river, the revetment has required repairs, and has been extended down-stream 800 feet. The Commission are of opinion that further repairs and extension will be required, and submit an estimate of $20,000 for this work.

GREENVILLE HARBOR.

A survey of this locality has been made. The trouble lies in the rapid caving of the river bank in front of the town. For its protection $136,000 will be required, in addition to the necessary plant, which will cost $50,000, making a total estimate of $186,000.

For details of work in this district, see report of Capt. C. B. Sears, Corps of Engineers, U. S. A., Appendix H.

FOURTH DISTRICT.

(Warrenton, Miss., to head of passes; 484 miles in length. Officer in charge, Maj. Amos Stickney, Corps of Engineers, U. S. A.)

HEADQUARTERS, NEW ORLEANS, LA.

This district embraces the improvement of the harbor of Natchez and Vidalia; the deflection of the waters of Red River from the Atchafalaya, and keeping open a navigable channel through the mouth of the Red River into the Mississippi River; a lock at Bayou Plaquemine, and the improvement of New Orleans Harbor.

NATCHEZ AND VIDALIA.

A recent survey of this locality shows that the caving in Giles and Marengo Bends still continues, but that it is most rapid and dangerous at Palo Alto Point, just above Vidalia. In all 55,000 feet of bank requires protection. Major Stickney, in his report (Appendix I), proposes to begin the protection at Palo Alto Point, using submerged spurs, such as are now being tried at New Orleans, and should the method be successful he proposes to extend it so as to cover the whole caving bank. The estimate for the work, on this basis, is $600,000, to which must be added $100,000 for a levee along Cowpen Point, designed to stop the flow of water across this neck in time of flood, which now seriously threatens the formation of a cut-off. The total estimate therefor, according to the plan proposed, is $700,000. If the spurs should not prove successful and mattress revetment be required, the cost would be at least double.

DEFLECTION OF THE WATERS OF RED RIVER FROM THE ATCHAFALAYA, AND KEEPING OPEN A NAVIGABLE CHANNEL THROUGH THE MOUTH OF THE RED RIVER TO THE MISSISSIPPI.

Under the recommendations made in the last annual report, and allotment made by the Commission from the annual appropriation, at the approach of low water operations with dredge-boats were renewed in Old River, with the view of keeping open navigation from the Red to the Mississippi River. The details of the work and the success attending it are fully described in the report of Maj. A. Stickney, Corps of Engineers, U. S. A. (Appendix I), to which reference is made.

During the execution of such permanent plan as may be adopted for the improvement of this vicinity, it may be annually necessary to resort to this temporary method of relief to navigation. The subject of permanent treatment is discussed elsewhere in this report.

NEW ORLEANS HARBOR.

At date of last report a mattress 400 feet in width was being laid in Carrollton Bend. Owing to delays in receiving material the rising river forced a suspension of operations, when 470 feet of this mat had been completed and sunk, and the work has not been resumed, owing to the more pressing necessity of protecting the bank in Gouldsborough Bend. Here the protection will consist of a series of sloping, submerged spurs, so designed and located as to move the current of the river away from the bank to be protected. These spurs rest on a mattress 200 feet wide and 350 feet long, laid on the bed of the river and normal to the bank, beginning at low-water mark. The spurs themselves are built up of timber cribs, filled with brush and loaded with stone. The width of the structure at the bottom is 60 feet, which diminishes by steps to 20 feet at the top, the size and arrangement of the cribs being such that the top of the finished structure will have a slope of 1 vertical to 3 horizontal from low-water mark to the bed of the river. The distance apart of the spurs will vary from 500 to 1,600 feet, according to the curvature of the banks. One spur is now well under way, and two more will probably be nearly completed with the funds now available.

The work is experimental, and its efficiency can only be determined after the subsidence of the next flood. The estimate for continuing this work and for completing the revetment in Carrollton Bend is $683,600.

For details of work in this district, see report of Maj. Amos Stickney, Corps of Engineers, U. S. A., Appendix I.

PLANT AND GENERAL SERVICE.

Plant in use in the several districts and in the general service during the time covered by this report:

Owned by the Government.—Two hundred and thirty-six barges, of which 30 were borrowed from the Missouri River Improvement; 47 quarter boats, 21 mattress boats and ways, 84 pile-drivers and hulls, 7 dredges and hydraulic graders, 6 dump boats, 3 derrick-boats, 2 pumping-boats, 8 screen boats, 9 docks, store and wharf boats, 5 machine and carpenter shop boats, 23 small flats, coal flats, and shells, 137 yawls and skiffs, 5 steam launches and tugs, 13 steam tow-boats, and quarters and shops at depots on shore.

The estimated value of the above September 30, 1884, was $1,276,000.

Chartered.—Fifty barges and 8 steam tow-boats and launches; the estimated value of which is $328,000.

The estimated value of the whole plant in use during the year is $1,604,000.

The general service of purchase, supply, and towing for the districts and the construction of plant was in charge of Capt. C. B. Sears, Corps of Engineers, secretary of the committee on construction, from November 1, 1883, to April 10, 1884, when he was transferred to the charge of the third district. The report of operations for the general service is presented by his successor, Capt. J. H. Willard, Corps of Engineers, to which reference may be made for details. (See Appendix E.)

Levee construction.—Under the allotment of $200,000 from the last annual appropriation the repairs of levees in the second, third, and fourth districts were continued. All information concerning this work is detailed in the reports of the executive officers of the above districts (appendices G, H, and I); and in the report of the board of district officers (Appendix M), to all of which reference is made.

LEVEES AND OUTLETS.

The difficulties of navigation on the Mississippi River below the mouth of the Missouri at no time arise from want of volume.

During the flood stages the supply is, of course, ample; and it is equally true that if the volume of discharge of even the lowest stages were constant, it would develop, in time, a sufficient channel for navigation.

Where the increase in width and area of section has become so excessive as to have seriously impaired navigation, scour and fill are less the result of absolute velocity than of the relative velocities in adjacent sections. In such cases the narrow and deep parts have greater areas of section, and therefore lesser velocities in the lower stages; while the wider and bar-obstructed sections at that period have lesser areas and greater velocities. At higher stages this relation is reversed.

An increment to the bars accompanies the flood because in the sections where they form there is greater area and less velocity than in the pool sections above. This subject is discussed by Mr. R. E. McMath (Report Mississippi River Commission, 1881, Appendix K, p. 242).

This condition is not a necessary result of the flood in a regulated river, but rather of those irregularities of the water-way, the correction of which constitutes an essential part of the plan of improvement projected by the Commission. With equal widths there should be no such interchanges of velocity at adjacent sections in high and low stages, and no differences of depth and area except at reversion points, where less

resistance makes lesser sectional dimensions equally efficient. A certain result of such uniformity of the elements of area as has always been insisted on by the Commission will be the correction of this local bar building by the flood.

To this bar growth at high stages there is a logical limit. When it has progressed far enough to maintain, by contraction, the velocity of approach from above, it necessarily ceases. This is true as long as the volume of discharge finds no other means of escape outside the bed of the stream. But when such opportunity is afforded, the bar growth is unchecked as long as a line of less resistance is open through the outlet. In the case of a cut-off the entire river is deflected in the direction of the increased slope, through the new bed, and within a year or two the abandoned channel is entirely closed.

Now, "when we consider that the slope of the river along its proper course averages scarcely one-third foot to the mile, while the banks slope away from the river 4 to 10 feet to the mile, it is easy to see to what an extent, during floods, the river is tempted to change its course," and that in such proportion as this temptation prevails, an effect similar to that of a cut-off in building a bar across the depleted channel is produced.

As the direction of the surface slope affects the direction of the thread of motion of the stream to all depths, so in case of both cut-off and crevasse the stream is turned, involving a loss of power in the impact against the bank; continuity of motion is broken, velocity is reduced, and a source of bar-formation is introduced. In the case of the crevasse, by the loss of volume, loss of velocity and ultimately of section is also incurred.

All plans proposed for the improvement of the river have for a common aim the establishment of uniform conditions at the same stages. As these conditions are interdependent, the securing of any one will tend to bring about the others. Thus uniform section will give uniform mean velocity, which in turn will induce greater uniformity of channel depth at any given stage. But, as an element of uniform section, the importance of uniform width by itself as a factor in producing uniform velocity is lessened so long as the escape of water from and return to the river, over banks varying 20 feet in height, as referred to the flood slope, allow inequality of flood velocity and depth as great as results from the present unequal widths.

Variation of discharge, at the same flood stage, in alternating parts of the river, from 1,000,000 to 1,600,000 cubic feet per second is as much an obstacle to stability of regimen as the existing difference of width; and improvement is only attainable by the control of both the area and discharge.

Uniformity of bank grade, therefore, as an element of uniformity of section and velocity and channel depths, assumes the same importance as uniformity of width, and should be extended and maintained over the entire length of the alluvial river.

The present grade of the banks with reference to its earlier and normal conditions is discussed in Appendix F, page 122, Report Mississippi River Commission, 1881. The levees as heretofore built, or as now recommended, cannot justly be considered as superimposed on, or added to, what would have been the bank height when carried unchecked to its natural limit; but as establishing, by artificial means, a grade which the river in the free exercise of its functions is ever seeking to attain, and to which, under normal conditions, it has approximated.

All observations bearing on this subject made by the Commission

sustain these views. In 1862 a break known as "Cubitt's Gap" occurred in the left bank of the river, about 4 miles above the head of the Passes. It rapidly enlarged until its section was about 34 per cent. that of the main river. The locality was surveyed in 1868, 1872, 1875, 1876, and 1877 by the United States Coast and Geodetic Survey. So we have a full physical history of the changes, which are thus stated by Mr. Marinden, assistant in charge of the surveys:

A noticeable feature in front of the "gap" and one which in a great measure must be traced to it as its cause, is the formation of a flat on the west bank as shown by the deep contours—the 24-foot curve more especially. Starting at a point on the west shore, 3,000 feet above the "gap," where all the curves run parallel to the shore, and the 24-foot curve is 260 feet from the 3-foot curve, which I have taken as the reference for convenience, being smoother than the shore-line, although running parallel to it, the 24-foot contour abruptly juts out towards the center of the river, till opposite the north point of the "gap" it is 820 feet from the 3-foot curve; then following down-stream and opposite the south point it is 920 feet; then after passing the opening of Cubitt's Gap it retreats toward the shore-line, so that about 2,000 feet below the south point it is 760 feet; 4,000 feet below it is 720 feet off, and 8,000 feet below the "gap" it is only 500 feet off, notwithstanding the gradual expansion of the Mississippi, which at the upper limit is 3,720 feet wide, and at the lower limit, 8,000 feet below the "gap," it is 4,815 feet in width, as measured between the 3-foot curve of each bank.

From the south point for a distance of about 1,300 feet down-stream, the two surveys compared are one of 1866, and the other 1876, which give a mean shoaling of 1.6 feet in the ten years, or 0.16 foot per year.

From the above-mentioned limit, 1,300 feet below the south point of "gap" to Cubitt's House, we have two surveys for comparison, one executed in 1866 by Assistant Gerdes, and the other by my party in 1877, giving an interval of eleven years; over this space there has been a mean shoaling of 3.9 feet, or 0.35 foot per year.

From Cubitt's House to the Head of the Passes, including all the space now covered by the works for the improvement of the channel-way into South Pass, we have two surveys again; one of 1866 by Assistant Gerdes, and one done under my direction in 1875 by Subassistant Braid. These surveys show a decrease in depth of 3.6 feet in nine years, or 0.4 foot each year. Where, however, the present jettied channel into South Pass is located there has been a decided deepening.

A subsequent survey, under the direction of the Commission, indicates the continued progress of this deterioration of the channel, which already threatens serious consequences to the maritime commerce of New Orleans.

The great loss of section, extending many miles below Malone's, Riverton, Bolivar, and Mound Place, and consequent upon these crevasses in 1882; and also the enlargement of the low-water section below Bonnet Carré, caused by the closing of this crevasse in the same year, were fully described in the last annual report of the Commission (1883, p. 16, and Appendix D, part 4, p. 171).

That such results are not only local but cumulative—throughout long reaches—is also indicated by observations. The guage records of flood heights, and the knowledge of facts connected with them, are not extended or complete enough to possess full authority. But if Memphis and Natchez are respectively selected as locations characteristic of unleveed and leveed fronts, and the existing record at each point divided into two parts covering equal time periods, and the means compared, it shows that the floods along the unleveed fronts have become greater during the latter half of the time covered by the record, while for the same relative time along leveed fronts they have been less. As there is no doubt of the increase, during this time, of one factor of sectional area—width—any tendency to greater flood heights along unleveed fronts means a more than proportionate decrease of the depth. The reverse of this is the apparent inference along the leveed front.

These two points, Memphis and Natchez, have been selected as fairly representative, having the longest records (57 and 82 years, respectively),

and being least affected by conditions not under consideration. An examination of the adjacent gauge records does not conflict with the inference drawn from those cited.

Again, the greater oscillation between high and low water at the mouth of the tributaries than at intermediate points has long been observed. It is presented here in tabulated form for the gauge stations at the mouths, and one intermediately located. It is represented graphically for all gauge stations in Plate No. 1.

Location.	Extreme.	Mean of last five years.
Cairo, mouth of Ohio	53.17	43.48
Fulton, intermediate	34.55	30.13
Helena, mouth of Saint Francis	47.20	38.57
Malone's, intermediate	34 05	33.91
Mouth White River	48.40	40.06
Lake Providence, intermediate	40.90	32.91
Vicksburg, mouth of Yazoo	51.10	39.85
Natchez, intermediate	50.30	38.04
Mouth Red River	48.50	39.39

These differences of relative level have generally been attributed to abnormal local flood elevations, caused by increase of volume at the mouths of the tributaries. The reverse of this is the truth. The difference is in the extreme fall and not in the extreme rise at these points. The bed of the river has adjusted itself to the annually recurring demands of the discharge by increasing its depth where they are greatest, and diminishing it where the discharge is dissipated by successive outlets.

It will be noted that, while by far the greater part of this difference of oscillation is in the depression of low water, yet there is some trace of abnormal flood-height. As the average considered includes three of the greatest floods on record, this would partially disappear were the term of years extended.

As the low water surface closely conforms to the controlling bars, it seems obvious that any such general elevation or convexity of bed as is found between the tributaries must make these bars more prominent and obstructive to navigation. Between the Yazoo and the Red rivers where levees have been comparatively well maintained, giving uniformity of bank height and discharge, this irregularity of low-water slope does not recur, and the navigation is three or four feet better.

Since such levees as have been built have never restrained the higher floods in safety, it cannot be expected that the "closing of existing gaps" will suffice to restrain volumes greater than those which have heretofore overwhelmed them; or to fairly test the principles upon which the recommendation of levees by the Commission is based. They must be higher, stronger, and more continuous than they have heretofore been built.

The grade of levees for the improvement of navigation should be at least the normal height of the bank of the river, or the height to which the bank would be built by such floods as recur with sufficient frequency to exert an appreciable influence in bank building or enlargement of water-way. This grade is approximately indicated by points on or near the margin of the river, well above general overflow, where deposit has been carried to a natural limit, unchecked by swift currents, and undisturbed by caving. This grade should be supplemented by

such additional height as will protect it against frequent injury or destruction.

Preparations must also be made in the grade for such increase of flood elevation as will at first and during the period of readjustment ensue from the introduction of greater volume between levees, when made more continuous. It is not possible to predict at present to what this will amount, and it is probable that an exact conclusion will only be reached by experience.

There are variables entering into the problem so subtle as to require additional investigation and study. This is now being given. Numerous observed facts indicate that guage heights for great discharge cannot be predicted by extending the curves constructed at low and medium stages with these elements as co-ordinates.

Many of the discharge curves of the observations of 1881–'82 and other years show great irregularities in this respect.

The high-water curve plotted on Plate I is of remarkable symmetry, while the breaks in the low-water curve, to which the profile of the bed conforms, are greater and more abrupt. The imprint of the flood's power is on the bottom and not on the surface. The slope has proved more inflexible than the bed. The capacity of the river has increased as the discharge.

This indicates that increment of volume will not be piled on top of the present flood heights, and that flood slopes cannot be changed over long distances from .25 to .75 per cent. The material of the bed does not possess stability under the frictional resistance which such increased slopes would indicate. Indeed, the impossibility of maintaining a slope greater than the average is indicated in the promptness with which slope is readjusted at every cut-off, where within a few hours the process of distribution is evident for very long distances, both above and below.

It is believed, to the contrary, that if an increase of .50 to .75 of the discharge can be arbitrarily and repeatedly withdrawn from and reinjected into the bed with very slight slope disturbance, it can be retained throughout the entire course of the river, and that even the maximum present discharge, by careful and judicious engineering, can be yet further safely increased, without ultimately raising the flood plane.

The following tabulated extract from Plate No. I compares high and low water slopes between the tributaries and a single intermediate station:

Location.	Slopes per mile.	
	High water.	*Low water.*
Cairo to Fulton	.435	.360
Fulton to Helena	.426	.490
Helena to Malone's	.400	.302
Ma'one's to White River	.327	.490
White River to Lake Providence	.327	.278
Lake Providence to Vicksburg	.276	.398
Vicksburg to Natchez	.291	.277
Natchez to Red River	.194	.218

It is assumed that no argument is here needed to attest the practicability of a levee system. It is thoroughly established by a large experience that faithfully-constructed levees, of sufficient proportions and age enough to have settled and become sod covered, will resist any pressure. Of 149 breaks in the Yazoo front in 1882, 147 were caused by

water running over the levees and eroding the rear slope. Caving of banks destroys far more than all other causes combined; but such loss will be reduced as caving is prevented, and permanence of bank will make the maintenance of levees of inconsiderable cost.

We therefore conclude that levees, such as have been herein described, are, in connection with an equalization of width and the prevention of caving, an important part of any general and systematic plan for the improvement of the navigation and the prevention of destructive floods; and we do recommend the construction of new and raising of existing levees along all parts of the river where the highlands are too remote to check the passage of large volumes of flood water outside the bed of the river; or, in other words, on the entire right and also on the left bank below Baton Rouge, and from the Yazoo River to Horn Lake, below Memphis.

As this recommendation extends to levees below Red River, where excellent facilities for navigation now exist, special reasons therefor seem necessary. It is not important here to repeat at length the principles on which are formed the regimen of a river so strictly alluvial as the Lower Mississippi. It has already been stated in the discussions of the Commission that the dimensions of the river are of its own creation; that a larger volume collected in one bed is discharged with less friction, other things being equal, and therefore with less slope, and more beneficent results to navigation and riparian interests; while subdivision of volume, on the contrary, meets proportionately more resistance in each minor channel, and therefore requires more slope.

It follows from this law that every step in the improvement of the river, including its delta, which begins at the junction of the Mississippi and Atchafalaya, should be in the direction of the assembling of its many outlets into one channel, while subdivision in passes or dispersion through crevasses is a grave error.

Besides these general reasons, there are others, local in character but of great importance, which will appear on examination of the physical condition of this region why the work of improvement should include this part of the river.

As has just been said, the point where the Atchafalaya diverges from the Mississippi is the true head of the delta, of which the Mississippi, Atchafalaya, and Lafourche are the only remaining passes or natural outlets. The capacity of discharge of neither of these channels is normally equal to that of the river above, just as in the subdelta neither the South or Southwest Passes or Pass à l'Outre has the capacity of the river above their joint head. But it is known that the Mississippi and Atchafalaya together cannot now discharge the volume of a great flood without disastrous overflow in the region they traverse.

Thus, in 1882, the total flood discharge from the drainage basin above the head of the delta reached 2,200,000 cubic feet per second, divided approximately as follows: Down the Mississippi, 1,450,000; through the Tensas Basin as overflow, 500,000; and down the Red and Black rivers, 250,000 cubic feet per second. Of this, 1,595,000 escaped down the Mississippi below Red River, and 281,000 down the Atchafalaya. The balance of 324,000 cubic feet per second entered neither stream, but escaped broadcast, to the Gulf, over the country.

The redistribution of a similar flood discharge, as effected by the completion of the levees above Red River, would be 1,950,000 from the Mississippi and 250,000 from the Red and Black.

Under these circumstances, one of two results is inevitable, and either would necessitate precautionary work.

In the first case the volume discharging down the Mississippi below Red River would be largely increased. This would require the temporary raising and strengthening of the levees on that part of the river. In the other case the water which now escapes in floods through crevasses in the Tensas front and returns in part to the Mississippi through Old River would reverse this movement if kept in the Mississippi, and would seek the lower levels of the Red and Atchafalaya through Old River with such force as not only to arrest the filling which now annually occurs in this channel, but also to deepen it and connect the deep water in the Mississippi with that in the Atchafalaya. This must be prevented at all hazards by work preceding the exclusion of flood water from the Tensas Basin.

These discharges of the Mississippi and Atchafalaya (respectively 1,595,000 and 281,000 cubic feet per second) are maintained for but a very short distance from the junction. Their capacity is rapidly reduced as they descend by repeated loss of volume over insufficient levees. Thus, while the Mississippi has a capacity at the gauge just below the mouth of Red River of about 1,500,000 cubic feet per second, at Carrollton, just above New Orleans, it does not exceed 1,000,000, as established by the following gaugings and computations:

	Cubic feet.
1851, Humphreys and Abbot	1,152,000
1858, Humphreys and Abbot	1,188,000
1880, Mississippi River Commission	987,000
1881, Mississippi River Commission	792,000
1882, Mississippi River Commission	921,000
1883, Mississippi River Commission	1,079,000

The surplus power of the flowing water is wasted over and through levees not sufficient in grade or strength to convert it into work. They offer less resistance than the bed of the stream. Thus, in 1884, the discharge at Red River gauge was upwards of 1,400,000, and at Carrollton about 1,000,000 cubic feet per second, while between were the following crevasses:

	Cubic feet.
Morganza	211,000
Waterloo	46,000
Bel Air	14,000
Guidry's	3,000
Davis	140,000
Total	414,000

Similar breaks occur whenever the discharge past Red River gauge largely exceeds 1,000,000 cubic feet per second. It is literally true that these levees are awash in every flood of magnitude for hundreds of miles. For long distances the waves from storms and steamboats overrun them, and a continual outflow is only prevented in many places by boards set on edge and sand-bags. It is, therefore. impossible safely to increase the slope even by a few inches in 300 miles, and without this the velocity cannot be increased nor the resistance diminished.

The mere introduction of additional volume into the upper end of a channel is not a practical compliance with the principles underlying the plan of the Commission. The condition of affairs just described has been substantially unchanged for upwards of fifty years—since the extension of levees up to Red River—and yet the volume discharged past that point, and recurring approximately with every flood, has not wrought out for itself below, in these many years, a sufficient waterway. It has run vagrant over the fields, rather than work. The re-

straint and concentration of the present supply of energy logically precedes its increase. Without this, additional volume only means waste of power and disaster from overflow.

While the enlargement of any outlet, natural or artificial, should be promptly and finally arrested, the levees from Red River down should be sufficiently raised and strengthened to restrain and apply effectively such power as resides in the mass of water now necessarily discharging and to be discharged between them before greater servitude is imposed, otherwise the treatment of the river becomes merely local, of partial measures inconsistent with a general plan and general improvement. Such a plan must protect any and all parts of the river against the direct consequences of its application to other parts by providing for the safe conduct to the Gulf of a more rapid discharge of the volume flowing from above.

Therefore, it is the opinion of the Commission that the building of levees for the improvement of navigation in the obstructed portion of the river cannot proceed indefinitely without involving damages to the proprietary interests below; and if this portion of the improvement to navigation is to proceed, provision must be made for strengthening and raising the levees in the lower portion of the river where navigation is now good.

This recommendation is not based on conditions which will be continually increasing or even permanent. No reason is apparent why the law that a larger volume of water flows through a bed adjustable by its own forces to its own needs, with less resistance and slope, should not ultimately be fully operative here.

During the transition period unquestionably the increase of work will be indicated by increase of slope, which will disappear as the equilibrium is re-established.

The following general order is believed to be judicious in the completion of a levee system. As its object is generally to enlarge the waterway, a common-sense analogy is found in the homely art of ditching. It should begin at the lower end. Each bottom, the Manchac, Lafourche, and Atchafalaya, constituting Lower Louisiana, the Tensas, Yazoo, White, and Saint Francis, should be inclosed in order, from below upwards.

In each bottom, as it is reached in the foregoing order, the most important levees, as restraining the greatest escape of water, should be first constructed.

RECTIFICATION OF RED AND ATCHAFALAYA RIVERS.

The situation at the mouth of Red River is one which has engaged the attention of the Commission from the beginning of its work. The subject has been discussed in some of its aspects in former reports, but the formulation of a complete and comprehensive plan has been deferred from time to time for the sake of the advantages to be gained by further observation, experience, and study. After full consideration of the matter the Commission is now prepared to present a plan for the treatment of this very difficult problem which is believed to meet all the requirements of the situation, and to be in point of practicability, safety, and economy the best that can be devised.

It is considered that any plan for this work ought to comprehend the prevention of the divergence of the Mississippi River into the Atchafalaya Basin, the closure of any depleting outlet at that point, either existing now or likely to be induced by changes which are reasonably

to be anticipated, and the preservation of the navigation of the Red and Atchafalaya rivers. That it shall provide for the immediate accomplishment of all these ends is not necessary, but that it shall provide contingently for them all is necessary to its completeness. It is necessary also that it shall harmonize with the conditions which will follow the exclusion of overflow from the Tensas and Atchafalaya basins.

Whether the levees necessary to prevent such overflow shall be erected by the United States or the States, or both, is not at all material. That these great areas of land will be reclaimed and occupied must be anticipated, and any wise plan for the treatment of the present situation must take that future fact into account, and not only harmonize with the conditions which will then exist, but must consist with the greatest safety of life and property in all localities liable to be affected by it. It has been the purpose of the Commission in the plan proposed to satisfy all these conditions.

For the full information of Congress on this important subject it has been thought well to present in some detail, not only that plan which is recommended by the Commission, as the best one, but all that have been considered.

TOTAL DEFLECTION OF THE RED INTO THE MISSISSIPPI.

A plan fully to accomplish this object would necessarily include the following parts:

1. A dam at or near the head of the Atchafalaya.
2. The connection of the dam with lines of levees of sufficient height to restrain all floods.
3. Locks at Plaquemine and the improvement of Bayou Plaquemine and the Grand and Atchafalaya rivers.
4. Raising the levees of the Mississippi below Red River.

These constituent parts will be considered in the foregoing order.

First. The selection of a location for a dam is limited to the Atchafalaya itself—in which one would be sufficient—and to Old River, where two would be required, one above the head of the Atchafalaya, between it and the mouth of Red River, and the other below, or between the head of the Atchafalaya and the lower end of Turnbull's Island. Both of these latter dams would extend from the right bank of lower Old River to Turnbull's Island. The selection of location would be controlled by the nature of the foundation, the materials available, the safety of the completed structure, and the relative cost.

The dam, if placed in the Atchafalaya, would be about 1,000 feet long. Its maximum height would be about 100 feet. The lower half would be built below low water, in a depth of about 50 feet, and the floods would bring a head of, say, 52 feet against it. The foundation would be in clay and sand. Dams in Old River would each be about 3,000 feet long, with a net height of about 60 feet. The flood head would be the same as that against the dam in the Atchafalaya. The foundation, however, is very much worse, consisting of the recent and loose deposit with which the bed of Old River is filled to a very great depth, and it is impossible to foresee to what extent a heavy dam would sink before attaining stability.

Three materials, to be used wholly or in combination, are available—brush, earth, and stone. Since the upper side of the dam is alternately wet and dry with every change of stage, and the lower side constantly exposed to atmospheric influence, the use of brush, from its perishable nature under these conditions, is quite inadmissible above low water. Its permeable and compressible nature also unfits it for use below low

water, with the great weight and head to which it would be subjected. The objections to the exclusive use of earth are the depth of water in which it is to be deposited and the necessity of completing a work of this material between two successive floods, or else of protecting it in an incomplete state against a flood, at great risk and cost. The objections to stone are its great weight and cost. These considerations decide the Commission, in case this work is done, to favor a dam consisting of two transverse stone retaining walls, built of riprap and extending up to low water, with outer slopes of 1 on 2 and inner slopes of 1 on 1. The distance between the crests of these walls will be the width of the base of an earthen embankment with slopes of 1 on 4, a crown of 40 feet, and of the requisite height. The earthwork should be thoroughly faced with stone.

This being the advisable construction of the dam, the Commission is confident, from the foregoing considerations, that the location in the Atchafalaya offers advantages of security and economy not found in Old River, and also that the dam should be placed below the mouth of the Bayou des Glaizes, through which stream a large volume of overflow enters the Atchafalaya. The contents of this dam will be about 3,000,000 cubic yards of earth and 200,000 of stone, for which an estimate of $2,000,000 is submitted.

Second. The overflow of the Atchafalaya Valley, as measured in the flood of 1882, is much greater than the discharge of that river within its bed. But as this is largely composed of Red River water, and the overflow would have free access to the stream through innumerable bayous below the dam, on either side, it is as important to exclude this overflow as the discharge of the stream itself. The work required to effect this would be the raising of the levees on the south bank of the Bayou des Glaizes, and up the left bank of the Atchafalaya from the dam to its head and along the south side of Old River to the Mississippi; for which an estimate of 1,400,000 yards, at 25 cents, or $350,000, is submitted.

Third. It is not presumed to be the intention of the Government to close inland access to the navigation of the Atchafalaya, Teche, and other streams of that system, 500 miles in length, through a country annually sending out $8,000,000 of agricultural products, as shown by the census of 1880, and for the improvement of which the plans and appropriations have already, from time to time, been made by the Government.

Locks at Plaquemine and the improvement of Bayou Plaquemine and Grand and Atchafalaya rivers are essential to connect this navigation with the Mississippi in case the above-mentioned dam is built, and are therefore considered as constituting an essential part of the project. An estimate to give 5 feet navigation has been prepared for this work, under the direction of the Commission by Maj. A. Stickney, Corps of Engineers, U. S. A., and is now submitted:

Locks and improvement of Bayou Plaquemine	$1,167,648 40
Improvement of Grand River	285,972 50
Improvement of Atchafalaya River	108,000 00
Total	1,561,620 90

Fourth. The gaugings made by the Commission in the vicinity of the mouth of Red River during the flood of 1882, established the following facts: In that year about 1,950,000 cubic feet per second reached the latitude of the mouth of Red River from the drainage basin of the Mississippi, of which 1,450,000 came down that river and 500,000

through the Tensas Basin as overflow. To this volume the Red and Black rivers added about 250,000 feet. The discharge below Red River was approximately distributed as follows: Past Red River Landing, 1,595,000; overflow between Red River Landing and Carrollton, 674,000; past Carrollton, 921,000; down the Atchafalaya, 281,000; and overflow through the Atchafalaya Basin, 324,000 cubic feet per second. The completion of the work required by the last river and harbor bill would, under conditions similar to those of 1882, have increased the discharge below Red River to 2,200,000 cubic feet—605,000 cubic feet, or 38 per cent. With the discharge actually occurring in that year the overflow was 674,000 cubic feet. With the above increase it would have been 1,279,000 cubic feet per second.

The difficulty and risk attending the execution of this plan are apparent from the following considerations: The conditions below Red River have been sustantantially unchanged since the completion of levees up to that point, over fifty years ago. Since that time the flood discharge at Red River Landing has repeatedly approximated 1,500,000 cubic feet per second, while the highest flood on record at New Orleans, that of 1883, gave, by actual measurement, less than 1,100,000. The surplus above this latter amount has been lost over and through insufficient levees. During these many years the larger volume passing Red River Landing has failed to excavate for itself sufficient waterway below. The reason is obvious. The power of the discharge above must be controlled and converted into work by levees offering greater resistance than the bed before the discharge can be increased. The measure of the work required of the river will first be indicated by an increased slope. But this is not possible on that part of the river under discussion, as the levees are already awash for hundreds of miles in great floods, and are only held by temporary devices. Hence they must be raised during the transition period and until readjustment is reached. In the next place, full security during and after the execution of the work cannot be assured without higher levees. It is entirely possible, and therefore must be provided for as a contingency of the work, that for a series of years there may be no flood of magnitude nor coincidence of floods in the two rivers. Thus, from 1877 to 1881, both included, the flood only once, and then barely, attained mean high-water mark, or 3 feet below the crest of the levee at Baton Rouge as determined by the average height of all known gauge records below Red River. During such a period the closure of the Atchafalaya might be completed without, in any one year, throwing into the Mississippi below a volume greater than the average flood discharge under present conditions. In such case no progressive enlargement of bed could be expected, and when after the completion of the dam a great flood should come, as did in 1882, or the floods of the Mississippi and Red should combine, the full effect of the work, as indicated in the raising of the flood-plane, would practically have to be encountered in a single year.

For the cost of the increase of levees, assumed to be necessary during the execution of the foregoing plan, estimates are submitted.

The estimates are divided into two parts, the first of which represents the amount necessary to place the present system of levees in such condition as they ought to be to safely restrain the floods now occurring, without any change of conditions at Red River. This is assumed at a mean raise of 2 feet in the grade.

The second part represents the additional work directly consequent upon the changes at Red River proposed by the plan now under discussion, assumed at 2 feet of additional height.

To restrain floods of the heights recently experienced on the Lower Mississippi the levees would have to be raised below Red River, and for this purpose a mean increase of height of 2 feet has been taken, and the amount required is $2,872,500.

The plan under consideration if executed will increase the volume of these floods, and necessitate a further increase of grade.

This is also assumed at 2 feet mean raise, and the amount required for this work would be $3,727,500; total, $6,600,000.

Total estimate for the execution of the project.

Dam	$2,000,000
Connecting levees	350,000
Locks and improvment of connected rivers	1,561,620
Raising levees below Red River	6,600,000
Total	10,511,620

The objections to this plan may be summarized in the statement that it is costly, difficult, and dangerous beyond the necessities of the case.

There is no evidence that there ever was a time when the entire discharge of the Red and Mississippi at their greatest floods passed, or could pass, down the Mississippi channel. The attempt proposed by this plan to compel such a result is an experiment with the forces of nature on an enormous scale and by a method which admits of no qualified trial. The head of the Atchafalaya being once shut up, the entire flood and all floods must be carried to the Gulf down the main channel.

Four feet is the height which has been assumed as the mean addition to existing levee grades below Red River necessary to provide for this increased discharge. This addition would not be uniform, but would exceed the mean along a considerable portion of the river's course. Crevasses are possible in the best-built and best-guarded levees; and when they do occur every foot of flood elevation above the level of the surrounding country adds greatly to their disastrous effects. At the elevation to which a great flood would be carried by the execution of this plan in some parts of the rivers below, where the adjacent country is highly cultivated and densely populated, a crevasse would come with a fury and destructiveness to which no former experience would furnish any parallel. The dangers here indicated would exist in a peculiar degree at the proposed dam across the Atchafalaya. Such a dam as would be necessary in this case, upon the foundation existing for it, cannot be regarded as a structure beyond the reach of accident, however well made or watched; and the breaking of such a dam, with a head of 52 feet against it, and the empty Atchafalaya Basin below it, would be an appalling event. That it would immediately precipitate one of the very disasters it was designed to prevent, viz, the cutting of a deep channel from the Mississippi River into the Atchafalaya Basin, would seem inevitable.

It may be said that the result of turning this increased volume down the main channel will be to increase its section by scour, and so provide adequate capacity of discharge without raising the present flood level. That its tendency will be to enlarge the channel is undoubtedly true. But the increased flood height must come first as a cause; the enlargement afterwards as an effect. How soon or to what extent the effect will follow the cause, no one knows. To assume that it will come in a few years, and act upon that assumption in a case so grave, is to stake tremendous consequences on the soundness of a theory.

It may be said also that the plan submitted hereafter by the Commission involves in its final execution a discharge in the main river below, of the same volume which this plan will require, less only the discharge of Red River. To which it may be answered that this is of itself a substantial difference, being equal to one-eighth of the discharge above Red River; and that in its relations to this river below it is a very important difference. When a great flood confined between levees has passed the point of safety, each inch of additional rise adds to the danger in an increasing ratio. To which may be added the more important fact that the plan submitted by the Commission has this exceeding advantage, that it can be executed by installments, and tested as it proceeds, without taking at once and irrevocably, enormous risks.

The presentation here made of this plan, and of the objections to it, have been extended to some length because a clause in the last law making appropriations for the Mississippi River appears to anticipate, if indeed it does not direct, the treatment of Red River in the manner contemplated in the plan here discussed. The funds available out of the appropriation were insufficient, however, even to begin a work of such magnitude. And inasmuch as the Commission is compelled, for the reasons stated, to disapprove the plan, it seems proper that the subject should be fully discussed at this time.

Other plans which have been proposed will be briefly discussed.

The separation of the Red and Atchafalaya from the Mississippi.

The separation of the Red and Atchafalaya from the Mississippi River has been proposed by extending and connecting the levees on the right bank of the Mississippi, above and below Old River, with a dam across that channel. This dam would have to be constructed with the same methods and materials as that previously discussed for the Atchafalaya. While it would not be of equal magnitude with that dam, either in length or height, or in the depth of water in which it must be built, the foundation would be in the loose deposit with which the bed of Old River is filled. The opening of the Plaquemine route, as previously described, would also form part of this plan.

The discharge below Red River, on the basis of the flood of 1882, would be increased 355,000 cubic feet per second, or to 1,950,000, which would still require some elevation of levees below.

The connection of the dam with the adjacent levees would be more expensive than in the previous plan. Estimates are submitted without recommendation.

Cost of dam	$1,200,000
Connecting adjacent levees, 2,000,000 yards, at 25 cents	500,000
Locks and improvement of Plaquemine, Grand, and Atchafalaya rivers	1,561,620
To make secure present levees below Red River, assumed, as before, at a mean raise of 2 feet in their grade	2,872,500
To provide for the increased discharge below Red River consequent upon the execution of this plan would require an additional raising of grade, which, assumed in this case at 1 foot mean raise, would require	1,927,500
Total	8,061,620

Major Stickney's project.

A project has also been submitted by Maj. A. Stickney, Corps of Engineers, U. S. A.

This plan proposes as its fundamental feature to raise the bed and

water surface of the lower Red and upper Atchafalaya by means of submerged dams, and will be found fully stated by its author in Appendix I of this report.

Major Stickney's estimate for the execution of his plan is $2,151,660.

If the increase of discharge down the Mississippi indicated by Major Stickney as the result of his plan were realized, we believe the following estimates for levees would be necessary as a part thereof.

To make secure present levees below Red River, assumed, as before, at a mean raise of 2 feet in their grade	$2,872,500
To provide for the increased discharge below Red River consequent upon the execution of this plan would require an additional raising of grade, which, assumed, as in the last case, at 1 foot of mean height, would cost	1,927,500
Total	4,800;000

Plan for the rectification of the Red and Atchafalaya rivers by preventing further enlargement of the latter stream and restricting its outlet capacity.

The object sought to be accomplished in the plan which is now described is the control of the outlet discharge through the valley of the Atchafalaya and the checking of the enlargement of its bed.

It is not the opinion of the Commission that the diversion of the Red River into the Mississippi is of the importance to the maintenance and improvement of the main stream that would render expedient the expenditure and risk that would be incurred by the magnitude of the project and the precautionary work necessary on the lower levees. Any reasons in favor of this plan are valid only in connection with the navigation of the tributary.

To some extent the repair of existing levees along the Tensas front, now in progress, will tend to reduce the strain upon the Atchafalaya, but to provide absolutely against any injury from the augmentation of floods in the main river below, some increase in the height of the levees below Red River will be necessary in this or any of the projects hereinbefore discussed.

The plan is as follows:

A series of brush-dams should be placed in the Atchafalaya, with the upper one below the Bayou des Glaizes, and the others at intervals not exceeding one-quarter of a mile. These dams should be built up to just below low water. It is the intention that these dams shall permit the passage down the Atchafalaya of a volume equal to the flood discharge of Red River, and in construction their height and the width between spurs can be so adjusted as to accomplish this result. It is also entirely practicable that these dams should be so located and constructed as to form part of a high-water dam, should the building of such be specially directed by Congress.

They should be constructed with a sill not less than 300 feet wide, up and down stream, and extending transversely up to the high-water banks. Above low water they should be heavily riprapped. The dam should be built upon this sill with concentric and diminishing cribs constructed as those now being used in New Orleans Harbor. While the ends of these cribs would reach about to low water, their concentric position would leave a depression not less than 5 feet deep over the middle of the crest to afford at all stages access to the navigation of the Atchafalaya.

The design for the dams as described has been used for purposes of estimate. If constructed, the details may be materially modified.

From the levees on either side of the Atchafalaya, and opposite the ends of the dams, earthen spurs should be built out as far as possible. These spurs, and any surfaces of adjacent levees or banks, where necessary, should be substantially riprapped. These spurs and the levees with which they connect, extending up the left bank of the Atchafalaya to Old River and thence to the Mississippi, and also along the south side of the Bayou des Glaizes, should be raised above any overflow.

Estimates for this project are submitted.

Six dams, with riprap and spurs, at $160,000 each	$960,000
Raising adjacent levees	250,000
To make secure present levees below Red River, assumed as in previous cases at 2 feet mean raise	2,872,500
To provide for the increased discharge below Red River, consequent upon the execution of this plan, would require an additional raising of grade, which, assumed as in the two preceding cases, at 1 foot increase of mean height, would cost	1,927,500
Total	6,010,000

Within a few weeks past the Commission made a careful personal inspection of the Atchafalaya River throughout its entire length. The water was at a low stage, and the opportunities for an examination of the stream and its banks were good. For a short distance from its head it has high banks and a deep capacious channel, which is gradually, but not rapidly, increasing in size. As it descends, the channel grows narrower and shallower, and the banks lower, and the evidences of recent enlargement gradually disappear. It is obvious that a large part of the water which enters between the high banks at the head is dissipated over the low banks below and finds its way to the Gulf in the form of general overflow. This overflow is so impeded in its progress by the dense forests of the swamps that it moves but slowly, and soon piles up to an elevation which limits the discharge from above.

Nearly, if not quite, all the water which flows down the Atchafalaya at the present time during flood stages comes from the Red and Black rivers and the Mississippi overflow into the Tensas Basin. There is now no tendency in lower Old River to enlarge; on the contrary, it appears to be closing. While present conditions continue there is not, in the opinion of the Commission, any immediate danger that a deep-water connection will be formed between the Mississippi and the Atchafalaya. On the contrary, there seems to be more danger that the bed of Old River will close and so sever the low water of the Red and the Mississippi rivers by a natural process, though of the future course of these changes it is impossible to affirm anything certainly. But the complete closure of the levees on the Tensas Front, an event likely to occur at an early date, will change very materially these conditions; and at flood stages of the Mississippi coincident with relatively lower stages in the Red there would be likely to be a large outflow through Old River. If this were left entirely unrestricted there would be danger of changes in the channels of Old River and the Atchafalaya, which might occur with suddenness and make their subsequent correction very difficult. The possible consequences of such changes would be so grave that no reasonable precautions against their occurrence ought to be omitted.

The submerged dams proposed in the last-mentioned plan will contract the present discharge capacity of the Atchafalaya only slightly, so that unless they shall be supplemented by levees to prevent the entrance of overflow water into the Atchafalaya Basin, the quantity of

Mississippi water escaping into that Basin will continue substantially unchanged.

This leads to the consideration of the Atchafalaya as an outlet, and to the question of its closure or restriction as such. The Commission entertains no doubt of the truth of the general proposition frequently heretofore stated, that the tendency of an outlet of substantial discharge is to impair the efficiency of the main channel below it. The complete closure of the Tensas Front will transfer the discharge of the present outlets along that front to the mouth of Old River and the space between that point and the foot of the Tensas levees. That the tendency of a permanent outlet so large and so sharply localized will be to impair the main channel below seems certain. The extent and rapidity of such impairment it is impossible to predict. But that it may result in the formation of a bar or series of bars great enough to obstruct navigation and in the abnormal widening of the channel, which is the usual concomitant of such bars, is possible.

The prevention of this escape can be accomplished only by cutting off the overflow into the Atchafalaya Basin by levees across its head. These, by preventing high water outflow through Old River, would also add to the security of that channel against dangerous enlargement, and so constitute a logical part of the plan proposed, whether that be considered as a means for the closure of an outlet merely, or as a precaution against the divergence of the Mississippi into the Atchafalaya Basin.

But, for the reasons already stated, the levees across the head of the Atchafalaya Basin cannot be constructed without exposing the country on the main river below to disastrous overflow, until the levees below Red River shall have been raised, and until that time the execution of that part of the plan must necessarily be deferred. The extent of such necessary additional levee height below Red River, and the probable cost of it, are given in connection with the statement of the first plan hereinbefore described.

The present recommendation of the Commission is confined, therefore, to the construction of the submerged dams described, designed to prevent further enlargement of the Atchafalaya.

The keeping open a navigable channel from the Red into the Mississippi River is not necessarily connected with any of the projects hereinbefore described, but in connection with the last plan described could, it is believed, be promoted by the following work. The limit to this improvement is the bar which invariably forms in the mouth of a tributary under the influence of back water from the Mississippi, and which the discharge of the tributary is unable to remove. Thus, the mouth of the Missouri goes down to 3½ feet, and of the White and Yazoo to about 3 feet.

It has been proposed to effect this by placing a low-water dam across Old River, between the Red and Atchafalaya, whose crest shall have an elevation of about 10 feet above the obstructions in Upper Old River, and thus deflect the Red River, when below this stage, down Upper Old River, which, before the present conditions, induced by the enlargement of the Atchafalaya, was the natural and better channel. The redevelopment of this channel would probably require the assistance of dredging and spur-jetties, for which no reliable estimate can be made. It is probable that work of this description would still be required if the entire flood discharge of the Red River were deflected in this direction. The cost of dam would be $125,000; probable cost of dredge and jetties, $275,000; total, $400,000.

While it is believed that the effect of this plan will be to deepen the access to Red River and confine the difficulty of navigation, which now extends over 6 miles, to its immediate mouth at the Mississippi, it is doubtful if the condition there admits of a depth of navigation greater than is now found at the mouths of other tributaries, or at the mouth of Red River itself before Shreve's Cut-off. The plan is therefore submitted as presenting this limited advantage, with an estimate, to enable Congress to judge of the advisability of its execution.

LEGISLATION.

The Commission renew the recommendation heretofore made that provision be made by law for the appropriation by the United States, through proceedings in the Federal court, of land and material needed in the work.

On this point reference is made to the suggestions of the last report, without repeating them here.

FINANCIAL STATEMENT.

Appropriation for salaries and expenses of the Mississippi River Commission, act of July 7, 1884.

Balance on hand December 1, 1883	$67,080 88
Appropriated by act approved July 7, 1884	75,000 00
	142,080 88
Expended from December 1, 1883, to November 30, 1884, including estimated liabilities	87,961 73
Balance which it is estimated will be required during the remainder of the fiscal year ending June 30, 1885	54,119 15
	142,080 88

Appropriation for surveys of Mississippi River, act of July 5, 1884.

Amount appropriated	$75,000 00
Expended to December 1, 1884	40,247 52
Balance which it is estimated will be required during the remainder of the fiscal year ending June 30, 1885	34,752 48
	75,000 00

The estimates of funds for fiscal year 1886, which were transmitted to the honorable the Secretary of War on July 25, 1884, are here repeated.

Estimate of funds for the Mississippi River Commission for the fiscal year ending June 30, 1886.

RIVER AND HARBOR BILL.

For continuation of surveys of the Mississippi River between the Head of the Passes, near its mouth, and its headwaters, now in progress; to make additional surveys and examinations of said river and its tributaries; to make such additional examinations and investigations, topographical, hydrographical, hydrometrical, as are necessary for maturing a plan for the permanent improvement of the entire river	$100,000

SUNDRY CIVIL BILL.

For salaries and traveling expenses of the Mississippi River Commission, and for salaries and traveling expenses of assistant engineers under them, and for office expenses and contingencies	$100,000

The estimates of funds for works of improvement for the fiscal year 1886, which were transmitted to the honorable the Secretary of War July 25, 1884, are here repeated.

Estimates of funds for the improvement of the Mississippi River for the fiscal year ending June 30, 1886.

For continuing the improvement of the Mississippi River from Des Moines Rapids to the mouth of the Illinois River	$500,000
For continuing the improvement of the Mississippi River from the mouth of the Illinois River to Cairo, Ill	1,000,000
For continuing the improvement of the Mississippi River from Cairo, Ill., to the Head of the Passes, including the improvement of the Red River at and below the head of the Atchafalaya	7,000,000

In addition to the foregoing, the following special estimates for improving the harbors named in the last river and harbor bill, as set forth in the body of this report, are recapitulated.

For improvement of the following harbors:

Columbus, Ky	$80,000
Hickman, Ky	270,000
Memphis, Tenn	75,000
Greenville, Miss	186,000
Vicksburg, Miss	20,000
Natchez, Miss	700,000
New Orleans, La	683,600
Total	2,014,600

FINANCIAL STATEMENTS, NOVEMBER 1, 1883, TO SEPTEMBER 30, 1884.

(Appropriations for improving Mississippi River, acts March 3, 1881, August 2, 1882, and January 19 and July 5, 1884.)

Balance available November 1, 1883	$1,023,913 33
Allotments since November 1, 1883	3,057,290 00
Unallotted, in Treasury	12,710 00
Deposited for loss of property and sale of fuel	60 50
Balance from previous appropriations for river above Cairo	22,632 53
Total	4,116,606 36
Expended November 1, 1883, to September 30, 1884	2,084,852 45
Balance available September 30, 1884	2,031,753 91
Estimated expenses to December 31, 1884	1,382,185 95
Estimated balance for carrying on work and care of property to January 1, 1885	649,567 96

Q. A. GILLMORE,
Colonel of Engineers, Brevet Major-General, U. S. A., President of Commission.
CHAS. R. SUTER,
Major of Engineers, U. S. A.
B. M. HARROD,
R. S. TAYLOR,
S. W. FERGUSON,
HENRY MITCHELL,
Coast and Geodetic Survey.

I have signed the above report with some misgivings as to the purport of the two articles entitled, respectively, "Levees and Outlets" and "Rectification of the Red and Atchafalaya Rivers," and I feel constrained to make my own conclusions a little more apparent.

The first article is valuable as furnishing all the information in the possession of the Commission concerning the effect of levees as means of improving navigation; but it seems to be implied that this information is now adequate to warrant a complete system, in which I do not concur.

The Commission has undertaken the reconstruction of levees along the fronts of the Yazoo and Tensas basins, with the expectation that these would improve navigation and determine the value of this means of improvement as compared with other means under trial. The results of these costly experiments have not yet been ascertained, and until benefits have been discovered from repeated surveys at low water there would seem to be no ground for recommending a complete application of the levee system.

This "complete application" would, it appears, necessitate the raising of all the levees now existing between Red River and the Gulf of Mexico, because it would precipitate into this—the most valuable part of the river—a greatly increased flood.

Before recommending or in any degree favoring such "complete application" of the levee system, I prefer to await the results of our own experiments, and I will add that these results will much exceed my expectation if they justify the extension of levee work 270 miles beyond the obstructed portion of the river, and the introduction of a change of regimen where no change can be for the better.

Relative to the second article, entitled "Rectification of the Red and Atchafalaya Rivers," I have felt that the Commission was not justified in assuming that the order of Congress to deflect the waters of the Red River from the Atchafalaya contemplated the augmentation of the flood heights and flood velocities below Red River, where no improvement to navigation demands it. I therefore regard the discussion of plans involving great systems of levees as irrelevant and unfortunate where not accompanied by explicit condemnation. To my mind the order of Congress finds its proper response in the plan recommended by the Commission for obstructions in the Atchafalaya and the suggested dam at the head of Turnbull's Island for deflecting the Red River.

HENRY MITCHELL,
Coast and Geodetic Survey.

Hon. ROBERT T. LINCOLN,
Secretary of War.
(Through the Chief of Engineers.)

NEW YORK, *December* 23, 1884.

1. In the preceding report the Mississippi River Commission has recommended the extension of the work below Cairo, to include the New Madrid Reach, and the commencement of a systematic revetment in seriously caving banks from Cairo down. It has submitted an estimate of $7,000,000 for work below Cairo, for the coming fiscal year, exclusive of harbor works.

Not concurring in either the recommendation or the estimate, it is proper to give my reasons for dissent.

2. The original estimate of the Commission for 38 miles of the Plum Point Reach was $1,432,000; and for 25 miles of the Lake Providence Reach, $1,238,000.

It is now certain that the cost of these works will be not less than *three* times the original estimate, and even yet it is not practicable to state with definiteness what the ultimate cost will be.

So far as the actual experience of the Commission goes, the loss of work has been large, but that experience is not yet extensive enough to show how much these losses can be reduced in future, nor, after works are completed, how much the annual cost of their maintenance will exceed or fall short of 5 per cent. per annum. As the advisability of the extension of the system of works over the whole river depends on the relation of the final cost of the system, and of its annual maintenance, to the value of the resulting benefits, I am not prepared to recommend any large extension of the appropriations or of the works till those costs are approximately known.

3. A majority of the Commission state, "We therefore conclude that levees, such as have been herein described, are, in connection with an equalization of width and the prevention of caving, an important part of any general and systematic plan for the improvement of the navigation and the prevention of destructive floods."

I am unable to learn from the report, exactly or approximately, what heights the levees "such as have been herein described" are to have, but as "preparations must also be made in the grade for such increase of flood elevation as will at first * * * result * * *," I infer that the levees "herein described" are to retain such large floods as occur every few years. I fully concur with the majority as to the necessity of such levees, to restrain destructive floods, and believe it to be the only method by which the great value of the bottom lands of the Mississippi can be fully developed.

I do not concur in the opinion that such levees will have any considerable value in improving low-water navigation. As I have stated in previous reports, the cause of bad low water navigation is excessive low-water width. It is only where such excessive widths occur that navigation is bad, and if by means of levees some hundreds of thousands of cubic feet per second of discharge at the top of the flood were added to a discharge which now is 1,200,000 or 1,400,000 cubic feet, while it might in some degree lower the bed of the river, unless it also narrowed the low-water river, it would give no sensible increase of low-water depth on the bars at these wide places. Where the river is now shoal and a mile or a mile and a half wide, it is difficult to see how levees on the bank of the river will produce any sensible contraction of width or sensible increase of depth, and it is only at wide places that increase of low-water depth is needed.

The river itself does not appear to support the theory that bad navigation is due to escape of flood water over the banks. The flood discharge of the river, as it now is, varies at different places between about 1,000,000 cubic feet per second at Carrollton and 1,800,000 or 2,000,000 cubic feet at the Ohio or at New Madrid. At New Madrid nature has supplied levees which practically confine the flood waters up to the highest stage. Here she has tried the experiment which the Commission are also trying, and the result is that immediately below New Madrid one of the worst, if not the worst, pieces of low-water navigation now on the river exists.

Again, if lack of flood-water which escapes into the river bottoms were the main or an important cause of bad low-water navigation, since below New Madrid the flood discharge decreases gradually to just above the mouth of the Saint Francis, where it does not much exceed 1,000,000 cubic feet, it would seem that on all the straight portions of the river

here the navigation should be bad. The fact is that interspersed between the bad reaches are others having no greater flood discharge than those above them, and yet where the navigation is good. If bad navigation arose from decreased flood discharge, there should be a marked deterioration in passing from New Madrid with 1,800,000 discharge, to just above the Saint Francis with 1,000,000 flood discharge. It does not occur.

It may be asked, What causes the excessive low-water widths which give bad navigation? If the comparisons of the old with recent surveys showing changes in the river, given in the plates of the Mississippi River Commission Report for 1883, be examined, it will be seen that at the same place, in widely different years, the river may now be wide and now narrow, and that there is in general a traveling of bends and peculiar forms down the river. This suggests that the special width or narrowness, and hence the good or bad low-water navigation at a given place, does not depend exclusively, nor even mainly, on the forces acting to-day, but rather that the actual form of the river at a given place is merely the recorded history of what has occurred there during many years past, and that where to-day the low-water navigation is good or bad, fifty years from now the state may be reversed, and that without any change in flood discharge.

If, in a straight reach, where navigation is now good, the river, changing the thread of its current from some slight cause, were to attack alternately one bank and the other—if this continued the result would finally be a wide river and bad navigation. The reverse process would turn a bad part of the river into a good one. These changes might occur just as well with a flood discharge of 1,800,000 as with one of 1,000,000 cubic feet; in other words, it might happen just as well with as without levees.

Not holding the opinion that bad low-water navigation is caused in any considerable degree by escape of flood water over the banks, I cannot attribute any value to levees as aids to low-water navigation commensurate with their cost.

Below Red River, levees for the improvement of navigation are not needed, as the navigation there is good, and any reactionary influence to improve the low-water navigation above would be very small.

4. For the Red and Atchafalaya rivers the Commission approves a plan which proposes to put a submerged dam across the Atchafalaya—ultimately to stop by levees all escape into the head of the Atchafalaya Basin except 281,000 cubic feet per second through the dam; and to build a low-water dam across lower Old River, between the Atchafalaya and the head of Turnbull's Island.

I concur in the propriety of checking the enlargement of the Atchafalaya by a submerged dam, as, if its enlargement went on indefinitely, the main Mississippi might go that way.

The effect of the levees would be to increase the flood discharge at New Orleans from about 1,100,000 cubic feet to about 1,900,000, and to require the levees to be raised there about 6 feet.

(In making this estimate the method used by me in the Annual Report of the Mississippi River Commission for 1883 has been followed. In reference to that method a majority of the Commission say: "Numerous facts indicate that gauge-heights for great discharges cannot be predicted by extending the curves constructed at low and medium stages with these elements as co-ordinates." I know of no one who proposes to use low stages for this purpose, and when, instead of "low and medium stages," medium and high stages are used, the method is in my judg-

ment the best at present available, and must be followed till the Commission present a better one to replace it.)

The plan, then, of stopping a large part of the escape into the Atchafalaya Basin proposes to require a large raising of the levees from Red River down at a great expense, and a permanent increase of danger to all the people living behind these levees from the greater overflow if these higher levees should be broken.

The advantages which may be supposed to follow from these levees are a theoretical improvement of navigation below Red River where it is now good, or a prevention of its deterioration, and a protection from overflow of an area of thinly-settled land in the vicinity of the Atchafalaya, small in comparison with that on the Mississippi below Red River. The disadvantages appear to far outweigh the advantages.

The Commission recommends the construction of a low-water dam across lower Old River above the Atchafalaya, and the formation of a channel on the north side of Turnbull's Island. The estimated cost is $400,000.

I fear that the opening of the channel would cost twice or three times the estimate, and that after the completion of the works the mouth of Red River would sometimes close unless dredging were used.

So long as the relative oscillations of the Mississippi and the Red may give nearly still water, loaded with sediment, in both lower and upper Old River, for many weeks at a time, it is very doubtful if in such cases the low-water flow of the Red River can keep, in dry seasons, a low-water channel open.

I should prefer to continue annual dredging rather than to execute a costly work whose results are so uncertain.

C. B. COMSTOCK,
Lieutenant-Colonel of Engineers and Brevet Brigadier-General.

Hon. ROBERT T. LINCOLN,
Secretary of War.
Through the Chief of Engineers.)

Itemized statement of expenditures for surveys and expenses of Mississippi River Commission.

[Appropriation of March 3, 1883.]

Items.	Services assistant engineers.	Services rodmen, &c.	Outfit.	Supplies.	Subsistence.	Fuel.	Repairs.	Transportation.	Mileage and traveling expenses.	Miscellaneous.	Totals.
Commissioners' salaries											$8,783 33
Mileage and inspection		$1,819 21	$45 90	$12 25	$1,318 44	$2,389 74	$4 50	$31 20	$4,611 52		10,232 76
Flood observations		1,566 70	290 47	218 22	476 06	333 20		101 00		$14 35	3,000 00
Transverse valley curves	$238 00										238 00
Steamer and outfit											17,530 47
Contingencies	500 00										500 00
Re-examination of Atchafalaya	400 00							1 50		210 90	612 40
Gauges	1,500 00	7,824 42	363 59	548 71	1,262 74	1,593 92	832 35	365 30		169 78	13,960 81
Precise levels	770 00	1,681 26	4 30	11 01			16 75	148 50		10 00	2,641 82
Reduction of field work	30,857 98	1,046 72	132 40	679 74			4 00	81 00			32,801 84
Publication of maps											2,569 65
Hydrography and topography	8,237 68	16,410 25	555 54	667 09	5,723 39	985 07	4,840 24	1,081 26		94 03	38,594 55
High and low water marks		1,969 41	47 30	268 62	827 51	712 33	120 45			83 35	3,978 07
Transfer to Maj. Amos Stickney											1,500 00
Totals	42,503 66	31,817 97	1,439 50	2,405 64	9,608 14	6,014 26	5,818 29	1,809 76	4,611 52	532 41	136,944 60

Item.	Services clerks, &c.	Rent.	Fuel.	Professional works and charts.	Furniture.	Supplies.	Transportation.	Stationery.	Telegrams.	Miscellaneous.	
Office	$7,707 61	$1,200 00	$410 81	$27 20	$23 88	$38 95	$56 74	$351 66	$356 22	$261 25	10,434 32
											147,378 92

SUMMARY.

Balance from appropriation August 2, 1882	$9,841 53
Appropriation by act March 3, 1883	150,000 00
Cash deposited, sale of fuel to officers	66 00
Total	159,907 53
Expenditures for fiscal year ending June 30, 1883	147,378 92
Balance	12,528 61

SMITH S. LEACH,
First Lieutenant of Engineers, Secretary and Disbursing Officer Mississippi River Commission.

Statement of appropriations allotted and expended under the Mississippi River Commission.

Act of March 3, 1881	$1,000,000 00
Act of August 2, 1882	4,123,000 00
Act of January 19, 1884	1,000,000 00
Act of July 5, 1884	2,070,000 00
Total	8,193,000 00
Balances from former appropriations for works below Cairo, July 1, 1882	272,628 38
Balances from former appropriations for works above Cairo, July 1, 1884	22,632 53
For sale of fuel and loss of property	60 50
Total	8,488,321 41

Expended to September 30, 1884.

Des Moines Rapids to Illinois River	30,914 73
Illinois River to Ohio River	65,450 66
Protection of easterly bank of Mississippi River near Cairo	5,408 91
New Madrid Reach	210,358 91
Plum Point Reach	2,030,896 80
Memphis Reach	390,992 05
Memphis Harbor	70,788 13
Lake Providence Reach	1,908,074 87
Vicksburg Harbor, dredging	61,812 12
Vicksburg Harbor, Delta Point	96,535 90
Survey of Helena Reach	8,000 00
Survey of Saint Francis Front, first district	4,873 11
Survey of Saint Francis Front, second district	4,000 00
Survey of Unleveed Fronts, third district	999 49
Survey of Unleveed Fronts, fourth district	902 12
Survey of Cubitt's Gap	137 14
Survey of Choctaw Bend	2,679 86
Observations at Carrollton	3,000 00
Closing Bonnet Carré Crevasse	15,000 00

LEVEES.

Second district.

Yazoo Front	80,950 00
Long Lake	15 55

Third district.

Yazoo Front	343,455 75
Tensas Front	361,653 53

Fourth district.

Atchafalaya Front	126,908 40
Tensas Front	444,186 63
Mouth of Red River	80,602 98
Natchez and Vidalia harbors	5,579 12
New Orleans Harbor	102,390 74
Total	6,456,567 50
Balance September 30, 1884	2,031,753 91
Estimated balances January 1, 1885	649,567 96

Respectfully submitted.

J. H. WILLARD,
Captain of Engineers,
Secretary Committee on Construction, Mississippi River Commission.

LIST OF APPENDICES ACCOMPANYING THE FOREGOING REPORT.

LIST OF PLATES ACCOMPANYING THE FOREGOING REPORT.

Description.	Designation.		Serial No.
	Appendix.	Plates.	
Mean low and high water slopes	....	I	1
Discharge observations at Paducah, Ky	D	I	2
Discharge observations at Columbus, Ky	D	II	3
Discharge observations at Helena, Ark	D	III	4
Discharge observations at Hays' Landing, Miss	D	IV	5
Equal velocity curves at Hays' Landing, Miss	D	V	6
Discharge observations at Red River Landing, La	D	VI	7
Comparisons of surveys of 1881 and 1883	F	III	8
Comparisons of surveys of October, 1883 and 1884	F	IV	9
Comparisons of surveys of October, 1883 and 1884	F	V	10
Survey near Gold Dust, October, 1884	F	VI	11
Survey near Bullerton, September, 1884	F	VII	12
Plan and elevations of pile dikes	F	VIII	13
Gold Dust Dikes	F	IX	14
Work at Fletcher's Field	F	X	15
Osceola Cross-dike	F	XI	16
Work at Osceola Bar	F	XII	17
Plum Point Dikes	F	XIII	18
Work at Bullerton Chute	F	XIV	19
Work at Craighead Point	F	XV	20
Map of Hopefield Bend and Memphis Reach	G	I	21
Chart of Lake Providence Reach	H	I	22
Discharge observations at Wilson's Point, La	H	II	23
Mean depth curves at Wilson's Point, La	H	III	24
Discharge section at Wilson's Point, La	H	IV	25
Comparative sections, Lake Providence Reach	H	V	26
Comparative section, Pilcher's Point, La	H	VI	27
Revetment work, Louisiana Bend	H	VII	28
Condition of works, Pilcher's Point, La	H	VIII	29
Condition of works, Cottonwood Point to Stack Island	H	IX	30
Map of Vicksburg Harbor and Delta Point	H	X	31
Revetment work, Delta Point, La	H	XI	32
Improvement below Louisiana, Mo	K	I	33
Bank protection near Cairo, Ill	L	I	34

APPENDICES.

Appendix A.

ANNUAL REPORT OF THE SECRETARY OF THE COMMISSION UPON THE FIELD WORK OF SURVEYS AND EXAMINATIONS.

Office Mississippi River Commission,
2828 *Washington Avenue, Saint Louis, Mo.*, *October* 20, 1884.

General: I have the honor to submit the following report of the work of surveys and examinations during the fiscal year ending June 30, 1884.

The survey boats and launches with their mess and field outfits have been kept in working order by the necessary current repairs. This remark applies to the instruments as well. No additions to either class of property have been made during the year except a stern-wheel steamer described below. No changes have been made in the organization or methods pertaining to the classes of work previously executed.

Gauge inspection.—This work has been given greater prominence during the year than it has had heretofore. A discussion of the hydrographs as well as the results of the few and irregular inspection previously made, had some time since developed the fact that the gauge records were far from reliable. The lack of correct river heights in previous years has in many cases substituted prolonged discussions for what would otherwise have been ascertained facts, and has in so far operated against the speedy elaboration of a definite plan of improvement. The principal source of error was found in the destruction of the gauges either by drift or ice, by the landing of boats, or by the scour or caving of banks.

At such times the keeper was obliged to use a temporary stick and by adding or subtracting the daily change, keep as well as he could a record of the stage of water, a process admirably suited to the introduction of large errors especially of the cumulative kind. To insure correct records the first step was to keep the gauges in position. To do this required that a party should visit each station frequently, carrying with it all necessary appliances for replacing and repairing gauges and bulletins.

Various plans which suggested themselves were tried without success, and a solution was finally found in the purchase and equipment of a small stern-wheel boat on which an inspector is constantly passing up and down the river inspecting the gauges, and by the assistance of the crew of the boat making all the necessary repairs. The party has also been able at a very slight cost to do a great deal of work formerly done by parties especially organized at considerable expense. She has also saved a considerable expenditure formerly necessary for transportation of supplies to field parties, and for towing their boats from point to point. The boat is named the Patrol; is 110 feet long by 23 feet beam; has engines 12 inches in diameter, 5 feet stroke, and costs with a single crew about $1,200 per month.

She left Pittsburgh, where she was built, in the latter part of July, 1883. She completed her furnishing and equipment at Saint Louis, and left for her first inspection trip early in August.

Her work for the eleven months ending June 30, 1884, is as follows:

Number of miles run	13 158
Number of piece miles towing	3,412
Number of ton miles of freighting	20,000
Number of gauge inspections made	103
Average interval (in days) between consecutive inspections at any gauge	58¼

Special surveys were made at Bonnet Carré November 5 to 10, 1883; 21 cross-sections sounded at Morganza November 14 to 23; 41 cross sections sounded at Waterproof Cut-off May 24 to 26; shore-lines run, water-levels determined, four cross-sections sounded, and discharge measured in cut-off and old river.

Low-water slope was determined October 11 to 31, 1883, from Saint Louis to New Orleans at 294 points.

High-water observations were made February 28 to March 27 from Memphis to New Orleans, during which time there were examined on the Yazoo Front, 116 crevasses; on the Tensas Front, 48 crevasses; on the Atchafalaya Front, 6 crevasses.

The results of these and previous measurements of the same character appear as an appendix to this report.

The following high-water discharges were measured: Saint Francis River, at Westbrook; Yazoo River, above Chickasaw Bayou; Bayou La Fourche and Mississippi River, at Carrollton, Red River, and Hays' Landings.

Stakes for measurement of caving banks were set in fifty-two caving bends.

Examinations of threatened cut-offs were made at Caulk's Point, Tarpley Plantation, and Georgetown Bend.

The total cost of the boat for eleven months, not including the salary of the inspector, was $17,089.80. Of this, $4,000 may fairly be assigned as the earnings of the boat in transportation and towing. The cost of high and low-water observations have been in previous years $5,000. The balance, about $8,000, is the pro-rata cost of the gauge inspections and special surveys.

In the prosecution of the regular surveys, the only field work done during the year has been the continuation of topography and hydrography from Cairo to New Madrid, from Caruthersville to Memphis, and from Commerce to Saint Louis Landing, a total distance of 248 miles.

The details are as follows:

Items.	First party.*	Second party.†	Third party.‡	For the three parties.
Number of miles of river	92	101	55	....
Number of square miles of topography	227	274	136	....
Number of square miles of hydrography	64	80	38	....
Total area surveyed (square miles)	291	354	174	819
Total field cost	$13,301 86	$12,558 97	$9,367 44	....
Cost per mile of river	144 59	124 34	170 31	....
Cost per square mile of survey	45 71	35 47	53 84	$43 01

*Assistant J. A. Ockerson. Randolph Point to Francis Chute, and Commerce to Saint Louis Landing.
†Assistant L. L. Wheeler. Caruthersville to Randolph Point.
‡Assistant C. M. Winchell. Cairo to New Madrid.

The work done in the previous years was 1,135 square miles, at $57 per square mile. The assistant engineers have continued to merit the favorable mention heretofore made of them. A reduction was reluctantly made near the close of the fiscal year in consequence of lack of funds. The work of the office having so increased as to make it impossible for me to supervise it in detail, the organization was recast, with three divisions, known as the topographical, computing, and clerical divisions, which were placed in charge of Assistant Engineers J. A. Ockerson and L. L. Wheeler and Chief Clerk A. E. Symmes, respectively. These gentlemen have conducted the work of their divisions to my entire satisfaction, and their efforts have been of great assistance to me.

The process of printing letters and figures on the manuscript maps mentioned in last report has been in constant use during the year, and has now established itself as a standard method.

It is therefore deemed proper to give in some detail a description of the appliances and the method of their use. This is furnished in the following extract from the report of the chief of the topographical division:

"STAMP FOR LETTERS AND FIGURES.

"This consists essentially of a piston carrying a type-holder in which words may be set up from common type, and a supporting frame. The piston is carefully fitted so as to move smoothly in a plane at right angles to the base of the frame. A spiral spring in the piston raises it from the paper after the impression has been made. The base of the frame is made so that the sides are parallel and at right angles with the line of the type when in the holder. By means of a ruler or T square the letters may be made always vertical and the different words in parallel lines. Words in curved lines may be made by using single letters, or by means of an elastic frame in the type-holder, which could be curved by an opposing screw.

"Words can be printed in any desired position by inspection or by pasting paper on the bottom and cutting out the same on a line along the type and marking in pencil the position of the word. The styles of lettering are only limited by the variety of type used. In the preparation of ordinary topographical maps it is desirable to have ten small fonts of letters, and figures for each, except those for State names and titles.

"When the same word occurs frequently, as in the cases of kinds of timber, character of river bed, numbers of contours, &c., the printing is done very rapidly. Even

where it is necessary to set up and distribute the type for single words it is much more rapid than hand work.

"In printing soundings, three disks are used. They are made with slots for the ten digits, and the figures fitting in snugly are held in place by friction. They can readily be replaced by new type when they become worn. It is evident that by the use of three disks any combination of figures from 0 to 999 can be made by revolving the disks so as to form the required number. After the desired combination is made, the figures are inked, and the disks all turned together down to an index, which shows when they are in proper position to print evenly. After inking they are then pressed against the paper at the point where the figures are desired.

"The best quality of printer's ink is used, and it is applied with a small roller made from the common roller composition."

Mr. Ockerson has continued his inquiries and experiments in this field, directing them to the development of means and methods for printing the conventional signs. The success thus far attained is set forth in the following extract from his report:

"HAND PRESS FOR PRINTING CONVENTIONAL SIGNS ON MANUSCRIPT MAPS.

"The first thing necessary in resorting to mechanical means for printing conventional signs is to obtain accurate types or molds from which stamps can be cast. Several efforts were made to engrave the signs in wood, but the results were never satisfactory. Experiments were then made in photoelectrotyping from small drawing, and after a number of trials a good electrotype was finally produced. Careful drawings were then made on sheets 6 by 14 inches in size, and accurate electrotypes obtained. These are the standards, and are never used except for the purpose of producing working stamps, which can be multiplied without limit.

"The drawings were prepared especially for maps which are to be reduced from scale of 1:10,000 to 1:20,000 by means of photolithography, and published by combining several detail sheets.

"The signs themselves are entirely satisfactory, and it remains to solve the minor details of manipulation."

With this in successful operation the only hand work on the maps will be the projections and outlines; a state of affairs in which the word "manuscript" will be almost a misnomer.

For details of expenditures I beg to refer the committee to the itemized statement submitted to the Commission.

SMITH S. LEACH,
First Lieutenant of Engineers, Secretary.

General C. B. COMSTOCK,
President Mississippi Commission,
Chairman Committee on Surveys and Examinations.

A 1.

REPORTS ON HIGH-WATER OBSERVATIONS.

1.—YAZOO FRONT FOR FLOOD OF 1882.

(By J. B. Johnson, United States Assistant Engineer.)

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., April 27, 1882.

SIR: I have the honor to report upon my high-water observations on the Yazoo front, made March 13 to 19, 1882. I very much regret that circumstances have forced me to present the results of my observations before I have had the time to make a study of various data bearing directly on the facts of this report. I submit, therefore, my determination of the discharge of flood water into the Yazoo bottoms, with the methods by which they were obtained, and can barely hint at some of the lines of research which should be pursued in this connection, and some of the very important results which should come from such investigations. I have had but two weeks' time to give to this entire report since returning to the office, which has proved entirely inadequate to the demands of the case.

I left Saint Louis March 10, on board the U. S. S. Emma Etheridge, arriving at Memphis Sunday, March 12. There I received your written instructions, sent from Louisville. They were of the most general character, simply asking me to find as

accurately and rapidly as possible the amount of water escaping through the levee and otherwise into the Yazoo bottoms, from Memphis to Vicksburg. Since the river had fallen nearly a foot, and was falling from one to two-tenths of a foot a day, it was evidently essential to prosecute the work with the utmost dispatch consistent with a fair approximation to correct results. I was not expected to stop at any one outlet in order to make a series of experiments bearing on the law of flow of water through crevasses.

I left Memphis March 13, and stopped that night at Norfolk Landing, at the outlet of Horn Lake. Here the business commenced. It is called 400 miles from Memphis to Vicksburg. This stretch was examined in six days. I was three days, however, in going from Norfolk Landing to Helena, a distance of about 60 miles, with 106 outlets.

From here to Mound Place, a distance of 150 miles, 41 outlets were examined in 1½ days. From Mound Place to Vicksburg, 160 miles, there were no outlets on the Mississippi bank. I therefore estimated or measured the discharge through 147 outlets, reaching over a distance of 210 miles, in 4½ days, being an average of 33 outlets and 47 miles of river per day.

From Commerce to Glendale, 45 miles; Friar's Point to foot of Island 64, 20 miles; from Riverton to Clark's Landing, Lake Beulah, 10 miles, and Catfish Point to Eutaw, 13 miles, I followed the line of the levee continuously in a skiff, seldom getting out of sight of it. This gives a total of 88 miles by river, but it was probably not more than 75 miles by levee. This work was very laborious, since it was mostly through the woods, where the difficulties of propelling a skiff were very great. The levee on these stretches was often many miles from the river, and the breaks were so numerous, and flow over the levee so great, that it was found necessary to follow it rigidly in order that no outlets should be lost. For the rest of the distance the outlets consisted of large breaks in the levee whose locations were well known to people who could be seen at the landings, and they were generally close to the channel of the river, so that I came to each locality by steamer, and then took a skiff and went out to the break.

My assistance consisted of the mate of the Etheridge, who did all the sounding, and the boatmen engaged on the steamer.

I.—*General description of overflow into Yazoo Swamps.*

The outlets for flood-water into the Yazoo bottoms are of three kinds:

First. Over the natural surface of the banks, where the levee has caved off into the river.

Second. Over the top of the levee.

Third. Through breaks in the levee.

It is a very noticeable fact that there are no outlets into the Yazoo below the natural surface of the bank. In this respect this bottom differs from the Saint Francis, as well as the Red and Atchafalaya river bottoms. There are many bayous leading from the Mississippi into the Saint Francis from 6 to 12 feet below the top of the bank, so that a stage of water 5 feet below the surface of the bank furnishes a very perceptible supply of water to the Saint Francis swamps. This is not the case with the Yazoo. The flood-waters enter this bottom over the bank in but two places, at and above Star Landing (De Soto Front post-office) for a distance of 9,300 feet, and opposite Island 64 for a distance of 3,300 feet. In both places the levee has caved off into the river.

Just above Sunflower Landing (Island 66) the old levee on river bank is gone for 2 miles. The levee from below, however, turns here and runs back some 8 miles to the Friar's Point county road, which is raised a few feet above the natural surface of the ground. As the river rises over its banks, which here are 5 or 6 feet below top of this flood, the water enters this open country, but after the levees broke above, there being a natural drainage towards the river at this point, the water flowed back to the river through this two-mile break. The water that entered here probably never reached the Yazoo, but was cut off by the Friar's Point road and Sunflower levee above mentioned.

At the height of the flood the water discharged over the top of the levee in almost one continuous sheet from a point 3 miles below Commerce to the railroad embankment back of Glendale, then at frequent intervals as far as Island 64. From Sunflower to the lower line of Issaquena County, Mississippi, 30 miles above Vicksburg, the levee was intact previous to this flood. This levee is under direct control of the levee board of Bolivar, Washington, and Issaquena counties. As the water neared the top of it the levee was raised from 1 to 3 feet on almost the entire distance, as far at least as Mound Place (100 miles by river), but the river raised over it in many places for miles together, especially in the vicinity of the mouths of White and Arkansas rivers and around Catfish Point. This would often cause large breaks in the levee, which would furnish sufficient relief to lower the water below the remaining levee surface.

Wherever the levee was built of "buckshot" or "bagasse" soil, however, the wear was very slow, and in many places the water had been running over four or five weeks without wearing down the top of the levee more than 1 foot.

The water commenced running over the levee in vicinity of mouth of Saint Francis and above February 12, and on March 14–16, the river having fallen 6 to 14 inches, the water was found running over 17,300 feet of levee from Commerce to Glendale, aside from 29,500 feet of crevasses where the levee was partly or wholly gone. At and below Austin the river had fallen 12 to 14 inches, but the water had overflowed almost the entire levee at top of flood.

On March 17–19 the water was not found running over the levee at any point below Glendale, although all the breaks below there were caused by water running over the top, and it doubtless did run over in many places for a short time where no breaks occurred.

The most of the water, however, which entered the Yazoo bottoms escaped through breaks in the levee. From the tabulated discharge it appears that at least 90 per cent. of all the water escaping from the Mississippi into the Yazoo bottoms went out through these crevasses and 80 per cent. escaped through twenty breaks, that being the number of discharges of 10,000 cubic feet per second and upwards. One hundred and eleven discharges through crevasses were seen and measured or estimated on the line of the levee from Horn Lake to Mound Place. Twenty-eight occur below Sunflower, in the "Lower District," where the levee has been well kept up. The "Upper District," extending from the bluffs below Memphis to Sunflower, has been abandoned since the flood of 1874, and, though having very few breaks in it, it had been worn down in many places, and in the three places mentioned above the levee had caved into the river.

There were two localities on the Yazoo front where the flood waters, having escaped over or through the levees above, were forced back to the river again below. One is at McKinney Bayou, 2 miles above Austin, and the other is just above Sunflower. The former is caused by an intervening ridge, but the latter is only the natural drainage across a point where the levee is caved off below.

The levees broke at Mhoon's Landing, 7 miles above the mouth of McKinney Bayou, February 12. This water was so obstructed by high land between here and Coldwater Creek that in four days (February 16) it commenced running over the top of the levee back into the river 3 miles below Mhoon's, and for almost the entire distance to the mouth of McKinney Bayou, which was four miles. On February 18 the levee across the mouth of the bayou (which had a culvert in it for drainage of swamp water back to river) broke, and on March 15 the bayou proper was discharging 10,300 cubic feet per second. The highest water occurred here March 5, and on March 15 it had fallen 14 inches. At this date I found 146,000 cubic feet per second passing out of the river at and above Mhoon's Landing, and only 84,000 cubic feet coming back to the river at and above McKinney Bayou. The balance, some 62,000 cubic feet, passed back into Coldwater and on to the Yazoo. From Maj. G. M. Helm, chief engineer of the levee board for the Lower Mississippi district, I have learned that on April 21, which was the height of the flood in that locality, there were eighty breaks in the levee from the lower line of Issaquena County up to Cottonwood, 10 miles above, caused by the Yazoo overflow pouring out, back to the river again, over the top of the levee. Cottonwood is 48 miles above Vicksburg by river. The maximum width of these breaks is 6,880 feet.

II.—*Methods employed.*

In regard to the methods employed to obtain these discharges, I wish to say in advance that they were only intended to be approximate. The rapidity with which it seemed necessary to do the work would not admit of any elaborate study or series of observations at any one locality.

I shall try to describe the methods employed in sufficient detail to enable one to enter a fair judgment of the reliability of the results. This, I am aware, is the more necessary since the magnitude of the overflow seems without reliable precedent.

In the first place, I may say that where the outlet was small, either over the levee or through a small break, both the width and velocity were generally estimated; but where the discharge seemed large, the cross-section and surface velocity were obtained.

The discharge over the bank was found by estimating the width of outlet (which was afterwards checked up by the charts or maps in the office), sounding the depth at intervals and running a surface float. But since, as stated above, 90 per cent. of the entire output into the Yazoo was through twenty crevasses, each of which discharged more than 10,000 cubic feet per second, it becomes evident that if the large outlets were carefully studied the smaller ones might well be hastily inspected without introducing any large errors in the result.

It was very important, however, that all outlets, whether large or small, should be seen by the engineer himself, if for nothing else, that he might know that the discharge was of little consequence. There are many ways of arriving at the approximate dis-

charge of a crevasse, simply by looking at it. If the observer approaches the crevasse in a skiff, from either side of the levee, he can form a very good idea of the discharge from the current setting toward or from it. These breaks are almost always in the woods, or, at least, there are trees on one or both sides of it, and a person familiar with forests can tell something of the depth of the water by looking at the trees and bushes standing in it. If, however, the observer is in a skiff, he sounds for the depth of water with his oar, and if this is not long enough he has his leadsman cast his lead. Learning thus the only fact which is not directly visible, he estimates the width of the crevasse (or the length of an arc of a circle around in front of the crevasse on the line of his soundings), and he also estimates the velocity in feet per second, by throwing in chips and ticking seconds in his mind and estimating the distance traveled. In this way he can readily arrive at an approximation to the discharge and know whether it is worth his while to stop with such an estimate or to employ more elaborate means to determine the discharge. I shall refer to these more accurate methods again.

I wish here to emphasize the reliability to a tolerable approximation of these methods of estimating.

The estimate is usually made on a section outside or inside of the line of the levee. A few soundings are made on this section, as the skiff moves along in front of the crevasse or overflow, and the depth of the section determined. If the discharge is small the skiff will probably not be stopped. A fair approximation to the velocity of the water can be made by seeing how rapidly it passes the trees on the line of our section. After having made a great many accurate measurements of surface velocity, by means of a float, one can closely estimate the velocity by seeing it pass any obstruction. Knowing then the depth and velocity on our section, we know the discharge in cubic feet per second per linear foot.

If the water were 8 feet deep on the auxiliary section and has a velocity of 1 foot per second towards the levee and only the top of the levee seems to be washed off, I would call the depth on levee 2 feet and velocity 4 feet; if all the levee seems to be washed out I could say depth = 4 feet and velocity = 2 feet; in both of which cases the discharge is 8 cubic feet per second per linear foot.

This coefficient of reduction from surface velocity to mean velocity will be considered later.

This method of estimating will account for so many even numbers in depth and velocity columns in the table of discharges. The width of discharge is then estimated (width taken as the length of our auxiliary section) and the observation is complete. This, as I have said before, is for small discharges.

It may well be said that such methods would involve very large personal equations—that two persons might arrive at very different results. This, of course, must be granted, but, in justice to myself, I should speak of my long experience in pacing distances as a rodman on precise level work, and later as an observer in the same kind of work where the distance is always paced and then determined by the wire interval on the rod. The observer's mind is constantly engaged in estimating distances, all of which estimates are at once checked up by the rod readings. One learns in this way to estimate distances of 100 to 300 feet very closely. Our distances in leveling are always given in meters, and so I find I can estimate a distance in meters much better than when I try to think in feet. When the width of a crevasse was measured by stadia, in this work, it was always obtained in meters too, so that the prevalence of such distances as 330 or 660 feet in the table is explained by their having been estimated as 100 or 200 meters.

I think I may say, too, that from my childhood I have been accustomed to hear a pendulum clock tick seconds, and that I have only to imagine myself as keeping time with the old clock in order to mark seconds very closely.

So much for the estimates which appear in this report. Such means of determining discharge were not used for more than 20 per cent. of the whole amount of overflow into the Yazoo. I may say, however, that the width of a crevasse, or the length of the section across which discharge was taken, which was usually greater than the width of the crevasse, was often estimated when the section was carefully sounded, and when the surface velocity was obtained by float. This was done because to get the width by stadia the skiff would have to pass from one side of the crevasse to the other three times in order to set the observer on one side, the stadia man on the other, go back for the observer, and then pass on along down the levee. This passing of the skiff was often dangerous unless it took a wide circuit around to avoid the rapid current, and then the time required was too great. The width was most difficult to measure, therefore, and most readily estimated, and hence it was often estimated when all other data was measured.

I think the error of estimates on such distances would not exceed 10 or 15 per cent. When, however, the discharge per linear foot was seen to be great, as for a deep section with rapid current, the width was measured by stadia, if possible, and it nearly always was.

The soundings were made by the mate of the Etheridge, an experienced leadsman, with a 12-pound lead.

The velocity, when measured, was found by means of a regular ship's log, presenting 18 square inches of surface to the current, the line being a small sea-grass fish-line, running on a fishing-reel, with the least possible amount of friction. The line was tagged with different colors every 10 feet, and the reel was provided with a catch which could be thrown and the run of float stopped instantly. In using it my leadsman held the watch and called every five seconds—as "Tick—five—ten—fifteen," &c. I noted what part of the line was running off the reel at the initial "tick," and would then throw the catch at some even five seconds.

The line was about 120 feet long, and from 80 to 100 feet was usually allowed to run out. If 80 feet had run out in twenty seconds, the velocity was recorded as 4 feet per second. This velocity was obtained, of course, across the line of the section sounded.

There are but four estimates in the tabulated list of discharges that were not made upon personal inspection and observation. They are—

OUTLETS.

	Cubic feet.
Horn Lake discharge	1,000
Thompson Place discharge	12,000
Lake Beulah discharge	14,700
Total discharge	27,700

RETURN FLOW.

Above Sunflower	37,000

Making a net reflow back to the river of 10,000 cubic feet per second, based on facts not obtained by direct personal observation.

I tried to reach the Horn Lake break on the evening of the 13th of March, by rowing up the Horn Lake pass, but the current out was so strong that I succeeded in going only about 2 or 3 miles. The data obtained are thought to be tolerably reliable. This break had flooded the entire country back of Norfolk Landing, clear up to the levee on the river front. The discharge given (1,000 cubic feet) is therefore rather too small than too large.

The breaks on the Thompson Place were not visited because I knew I could get very reliable information from Captain Stancell, levee contractor, and because it would have delayed the work a half day. I saw a break some two miles above and another some three miles below, and so could form some satisfactory estimate of the velocity the water would have, for the fall through the levee would be about the same.

For the breaks on Lake Beulah that were not visited, I have this excuse. The steamer had gone from Riverton around to Clark's Landing in Lake Beulah, and I started to follow the levee in a skiff. After passing Judge Miles's the difficulties of getting a boat through became so great that I found I could not possibly follow the levee all the way to Clark's before dark. The levee also was very low—about four feet—and for the two or three breaks found in it the current was only three feet per second. At Clark's I learned that Walter Helm, assistant engineer to Levee Board, had just made a personal inspection of all that line of levee, and I could learn the facts from him at Greenville, which I did.

For the return flow of water to river above Sunflower, my data is more unsatisfactory than for any other portion of the discharge. I had been told, before starting out, that the levee above Sunflower ran eight miles back from the river and then straight to Friar's Point. At Friar's Point I learned this was a mistake, and that the levee came to the river again in the next bend below. I followed the levee continuously from Friar's Point to Island 64 and found that my first information was wholly erroneous. At a point nearly opposite Saint Louis Landing I found a small break in the levee where the water was running back to the river. This was some five miles above Sunflower. They told here that the levee was complete to Sunflower. I therefore took steamer to Sunflower, and was there told again the same story. They must have meant the levee running straight back from Sunflower to the Friar's Point road, which was intact. I therefore passed on down. On arriving at the office and consulting the field sheets of last winter's survey, I find that the old levee that follows the river from Friar's Point down has caved off in the river for two miles above Sunflower, and Assistant Engineer J. A. Ockerson says that in the high water of 1881 water was running out of this opening into the river. He also furnished me with the elevation of a high-water mark of 1881 at this point, and the general elevation of the bank referred

to same datum. Knowing the excess of flood of 1882 over that of 1881, I derived the average depth of water over this section for this flood. From the field sheets it is evident there is a natural drainage back to river here from the bend above, and from the observed velocity through the break five miles above, I thought there might be an average surface velocity of one foot per second back into the river for this entire section of two miles width. This gives a return flow at this point of 37,150 cubic feet per second.

III.—*Results.*

In appendix to this report will be found a tabulated list of all discharges, whether out of, or into the Mississippi River, on the Yazoo Front, from Memphis to a point some 48 miles above Vicksburg, where the Yazoo commences discharging, even over the levees, back into the Mississippi. No data were obtained on this discharge at the mouth of the Yazoo. This table furnishes—

(1) The approximate location of the outlet.
(2) The kind of outlet; whether over bank or levee, or by crevasse in levee.
(3) Date of first discharge, or date of break in case of crevasse.
(4) Date of observation.
(5) Stage of water below the maximum at time of observation.
(6) Width of outlet.
(7) Mean depth of outlet.
(8) Surface velocity of water.
(9) Discharge in cubic feet per second.
(10) The partial summation of discharge for the several sections of the river.
(11) The continued summation of the net discharge from the Mississippi River into the Yazoo Swamp.

The date of the break was obtained in nearly all cases from people in the vicinity, and when this could not be done, it was taken as the date of the water commencing to run over the top of the levee.

A column giving "cause of break" would have been added, except that in all cases but two the breaks were caused by the water running over the top. In one of these cases the levee was supposed to have been cut, and in the other, which was the upper break at Bolivar, there was an escaping of water at the bottom for several days, and then the levee gave way all at once, bottom first apparently. This could have been prevented by building a "run-around," but the forces were all exhausted, having for days and almost weeks been working night and day in raising the tops of the levees.

The methods of finding width, depth, and velocity have already been discussed. The coefficient of reduction from surface to mean velocity has, however, not yet been treated. And this is, I think, the most uncertain element in the whole problem. I have used 70 per cent. as the ratio of mean to surface velocity. I can give no better reason for using this ratio than the general fact that this is about the smallest ratio on record for this relation in natural channels, and my judgment is that this is about right for crevasses. The whole question of the flow of water through a channel of rapidly diminishing depth, which is about the same as that over a submerged weir, seems as yet almost wholly unsolved. Where the flow through a crevasse is over the natural surface of the ground, with no excavation or "wash" on the line of the levee, as was the case at Trotter's Landing, the relation of surface to mean velocity would be that of ordinary flowing streams, perhaps, but where there is a deep gorge washed out from the river bank, as at Riverton, or on Sunflower Lake, below Austin, which may be 30 or 40 feet deep in the line of the levee and between it and the river, but rapidly shoals up after it passes the line of the levee where the water can spread in all directions—in such a case, there can be no doubt that the ratio of mean to surface is much less than where the depth continues indefinitely. In the case of a deep hole excavated in the line of the levee, also, the ratio of mean to surface is very different from that of ordinary streams. In this case, however, I usually tried to get a section outside of the "wash." Where I could not do this, as was the case at Austin and at Bolivar, I would decide whether or not the entire section should be considered available for discharge. In two cases at Austin I thought that about one-third of each cross-section should be deducted for the effect of the eddies near each side, but in no case have I deducted anything for depth. The reason for not doing so was that in all cases where these holes existed, their effects were at once evident from the sudden checking of the velocity, and the vigorous boiling of the water as soon as the deep section was reached. The rapid exchange of position vertically, of the particles of water, caused by these immense boils, would, of itself, tend to give a uniform velocity to the entire cross-section. This checking of the current was so marked that in some places it was evident that the surface velocity must be compensated by a more rapid velocity below. A very valuable observation, bearing on this subject, was obtained at the upper Bolivar break.

This break, as measured by stadia, was 1,150 feet wide. The upper half of it was just back of a large hole which had been excavated by a previous break. On the lower half the levee had gradually washed off, but without excavating any hole. The mean depth on the upper half was 39 feet, the maximum being 48 feet. The mean depth of lower half was 14 feet, depth being very uniform. The levee here was about a quarter of a mile from the river and back of an open grove of second growth cottonwoods. There was a fall of about 2 feet from the river bank to the line of the levee, and an apparently uniform slope through the levee. The depth of overflow outside the levee was very uniform, being from 12 to 14 feet. The water passed into this break from all directions with a uniform velocity, *the discharge per linear foot evidently being nearly uniform for the entire cross-section.*

The surface velocity in the deep section was found, by float, to be 2½ feet per second (being 75 feet in 30 seconds), while the surface velocity on the shoal section was 6 feet per second (being 90 feet in 15 seconds).

Applying our coefficient of $\frac{7}{10}$ to reduce surface to mean velocity, we obtain a discharge per linear foot of 68 cubic feet on the deep section and of 59 cubic feet on the shoal section. This is an extreme case, and we obtain a discharge in the deep section 15 per cent. greater than in the shoal section, which is doubtless quite within the limits of error for each measurement.

So far as my observation goes, therefore, I think little or no deduction should be made for the depth of the hole, provided a fair average surface velocity could be obtained. The prevalence of this disturbed condition of the surface makes it difficult to obtain a surface velocity which will be near the average. For this reason it is best to try to get the section for discharge where there is a more even flow. I am sure it is a grave error to assume that the rate of flow across one of these holes is the same as though there were no excavation there. The most casual observation would correct such an impression. I do not think the existence of the enlarged section would materially increase or diminish the flow of water across it, but I do think that when the surface velocity is taken across the enlarged section, the entire cross-section should be used, except when there are well-defined eddies at the sides.

As to what coefficient should be used to reduce to mean velocity, I know of no way of determining it except by obtaining vertical velocity curves for the various conditions. Even then the new local conditions found at every crevasse would so modify the problem as to make it inapplicable.

When I started out I obtained permission to engage a number of observers to read a gauge outside and one inside the levee at the most important crevasses, and also to note the rates of widening of the crevasse from stakes on top of the levee that I would locate. I thought in this way to obtain data that could be used in deriving some formula for computing the flow through the crevasse for the remainder of the flood. I was soon convinced, however, after taking the field, that no data obtained at one locality could be applied at another, for it is the local conditions, far more than the slope through the crevasse, which determines the discharge. I therefore abandoned the scheme. The conditions here referred to are such as trees and bushes on one or both sides of the break, obstructions in the crevasse itself, such as fallen trees, and the velocity of the water towards the crevasse as it approaches the opening. In the case of the Bolivar break, the one above Delta, and many others, the water came pouring down through the woods with a tremendous current, and entered the crevasse at 6 to 8 feet per second. Here it was checked up to 2 or 3 feet per second if there was a deep wash-out, but if there was little enlargement of the section it passed right on through with about the same velocity, and perhaps with very a little fall, through the levee. On the other hand, if the discharge was not sufficient to give the water a strong entering current, or if the crevasse was on the river bank where the water had full and free access to supply the discharge without generating any great velocity, the fall through the levee might be 1 or 2 feet without creating a velocity of more than 3 or 4 feet on the line of the levee. Data obtained, therefore, from an elaborate study of one crevasse would probably give vicious results when applied to other localities.

A good example of this is seen in Humphreys and Abbot, pp. 283–301. A formula obtained from a study of the Bell crevasse was applied to the crevasses on the Yazoo front in 1858, and the computed discharge would have drained the river dry before reaching Vicksburg. By an elaborate investigation an effort was made to find what the discharge into the Yazoo should have been, and so a coefficient of correction was obtained to apply to the formula when used for other localities, and this coefficient was ⅓. It was concluded therefore that the formula gave three times too large a discharge.

If it is thought that the coefficient of .7 is erroneous, any other can be readily applied by dividing the total discharge by .7 and multiplying by the new coefficient. I can only give it as being in my judgment, and the light of such data as I have, very nearly correct.

From the tabulated discharge in the appendix we may make the following—

SUMMARY FOR YAZOO BOTTOM.

I.—*As to locality.*

	Cubic feet per second.
Outflow above Mhoon's	146,000
Return flow, Mhoon's to McKinney Bayou	64,000
Net outflow to McKinney Bayou	82,000
Outflow, McKinney Bayou to Austin	40,000
Outflow, Austin to Glendale	168,000
Outflow, Glendale to Island 64	177,000
	467,000
Return flow at Sunflower	37,000
Net outflow above Sunflower	430,000
Outflow, Sunflower to Concordia	59,000
Outflow, Riverton break	107,000
Outflow, Lake Beulah	32,000
Outflow Bolivar breaks	128,000
Outflow, Catfish Point	6,000
	762,000
Return flow on Catfish Point	1,000
Net outflow above Catfish Point	761,000
Outflow at Mound Place	21,000
Total net overflow into Yazoo	782,000

II.—*As to time.*

Outflow, January 21, 1882	20,000
Outflow, February 10, 1882	40,000
From breaks occurring February 10 to 19, from Austin to Island 64, resulting from the first Helena rise, there was a net discharge February 20 of, say	320,000
	360,000
From flow back to river over levee and through McKinney Bayou break, which occurred February 18, there was a return flow February 20 of about	40,000
Net overflow February 20	320,000
From breaks occurring February 28 and March 1, with increased discharge of upper breaks, there was a net increase of above overflow by March 5 of, say	300,000
Net discharge March 5	620,000
From breaks occurring March 5, together with increase of discharge of other breaks, there was a net overflow March 9 (being the maximum stage at Memphis, Mhoon's, and Helena) of, say	180,000
Net discharge March 9	800,000
From direct observations the net discharge March 14, 1882	780,000

From an inspection of the gauge curves I would think the discharge had diminished to 100,000, or perhaps 50,000 cubic feet, by April 20, when the river had fallen 7 feet at Helena and 5½ feet at Arkansas City, below its maximum.

I do not think a very fair estimate could be made of the time of ceasing to overflow, for it will depend largely on the amount of shoaling back of the large breaks. It is well known that great quantities of sand are deposited over the natural bank back of these large discharges, which sometimes will raise the surface several feet, and so cause the discharge to cease that much sooner.

The analysis of the overflow given above is accurate *as to locality*, but the estimates as to time cannot be relied on with any degree of certainty. The dates of breaks as given in the table of discharge are reliable, and with sufficient time and study one might derive a fair approximation to a *curve of discharge* into the Yazoo from, say, January 21 to April 21, which are about the limits of flood discharge.

The following table gives an analysis of the widths of the discharge sections:

Kind of overflow.	Outlet.	Return flow.	Total submerged.	
Width over bank	12,600 feet.	10,500 feet.	23,100 feet.	4.4 miles.
Width over levee	16,640 feet.	8,040 feet.	24,680 feet.	4.6 miles.
Width through crevasses	37,000 feet.	4,890 feet.	41,890 feet.	7.9 miles.
Totals	66,240 feet.	23,430 feet.	89,670 feet.	16.9 miles.
Totals in miles	12.5 miles.	4.4 miles.	16.9 miles.	

IV.—*Discussion of result.*

The above is as thorough an analysis of the observed facts as I have had time to make. If proper maps were accessible it would be interesting and profitable to study the direction and course of the flood waters after passing the line of the levee.

Another profitable line of research is the effect these outlets had on the stage of water, velocity of current, shoaling of bed, &c.

Their effect on the stage is in many cases plainly apparent on the gauge curves, submitted with this report.

GAUGE CURVES.

I have plotted the curves of eight gauges on the Mississippi, one on the White, and one on the Arkansas Rivers, from November 2 to April 22, and of seven others on the Mississippi below Cairo, through the period of the flood. These are found on Plate I.*

On Plate II will be found the gauge-curves of six points on the Mississippi, viz, Cairo, Memphis, Helena, mouth of White River, Lake Providence, and Vicksburg. These curves are made to coincide both as to time and elevation. For elevation they are all referred to extreme low water at their several localities, and for time they have all been made to coincide with the Cairo curve, by moving the other curves bodily to the left as many days as it took the December wave to travel from Cairo to the given point. In this way the sharp and exceedingly symmetrical December rise has been used as an index by which to locate the curves on this plate.

The curves in Plate I are plotted directly from their gauge readings, without any reference to low water or any common datum. They all seem to have retained the same zero except that at Mhoon's Landing, which was evidently moved about a foot between March 21 and 26.

By comparing the Cairo and Helena curves on Plate II, one can see at what stage the water commences to escape into the Saint Francis swamps from the Mississippi. It is at 36 feet on the Helena gauge and 29 feet on the Memphis gauge. This is shown by the divergence of the two curves at this point. The river at Helena ceases to rise as rapidly as at Cairo, comes to a maximum seven days after it would have done had the river been within its banks, being January 10, instead of January 3, for a maximum at Cairo on December 31. Then for a fall at Cairo of 2½ feet we have a fall at Helena of two-tenths of a foot before the next rise at Cairo forced it up again.

Until the water commenced to escape into the Yazoo, January 21, the whole story of the relations of Mississippi to Saint Francis is told or, at least, indicated by the relation of these two curves (Cairo and Helena). (See Plate II, Fig. 1, December 26–January 21.)

In this connection, the December rise, from 24 to 34 feet, and back to 22 feet, all from November 2 to December 16, is of great benefit. Here the river did not get above its banks, neither did it escape through any of its outlets into the Saint Francis, and the curves are not only strictly similar, but at Cairo and Helena they are almost identical in position; also at mouth of White River and at Vicksburg. These two latter, however, are some 2 feet higher throughout this entire period, owing to a rise of 8 feet in the White River and of 3 feet in the Arkansas.

A very noticeable feature of the Memphis curve is, that for all its stages it is far below both the Cairo and Helena curves. At time of overflow this would be expected, as a result of the Saint Francis swamp overflow, but we see that a 21-foot stage at Cairo and Helena (being exactly the same elevation at the two points—see Plate II, Fig. 1) corresponds to a 14 4-foot stage at Memphis. Also a 34 to 35 foot stage at Cairo and Helena (top of December rise) gives only a 26.2-foot stage at Memphis. The top of this wave was wholly within the banks, with no escape from outlets. For the maximum of January 1, where there was a small discharge through bayous into the Saint Francis, a stage of 40.6 at Cairo and 39.5 at Helena gave but 30.4 at Memphis.

For the next maximum, January 31, with a large escape into the Saint Francis, a stage of 48.8 feet at Cairo, and 46.7 feet, ten days later, at Helena, gave but 35.3 feet at Memphis.

*These plates have not been published.

For the highest point of the flood, about February 28, a stage of 53 feet at Cairo, and of 47.2 feet at Helena, gave but 36.1 feet at Mempis.

Using extreme low water for a common datum, we have, therefore:

Stage of Cairo.	Stage of Helena.	Mean of Cairo and Helena.	Stage of Memphis.	Mean Cairo and Helena minus Memphis.	Remarks.
6.4	6.3	6.35	2.1	4.25	No swamp discharge, September, 1881.
17.5	17.4	17.45	11.75	5.70	No swamp discharge, November, 1881.
21.0	21.0	21.0	14.4	6.6	No swamp discharge.
34.2	34.8	34.5	26.2	8.3	Do.
40.6	39.5	40.05	30.4	9.65	Small swamp discharge.
48.8	46.7	47.75	35.3	12.45	Large swamp discharge.
53.0	47.2	50.1	36.1	14.0	Do.

A curve showing this relation is herewith presented. Plate II, Fig. 2.

The common datum of extreme low water was for Memphis and Helena, December, 1872, and that for Cairo was 1871. It is probable the Commerce Cut-off and other changes since these dates have changed the low-water slope so that the same extreme low-water stages at Cairo and Helena would give a stage 3 or 4 feet lower than that of 1872. To show this change of the regimen of the river at Memphis, relatively to Cairo and Helena, since the cut-off at Commerce in May, 1874, I have taken a series of maximum and minimum stages at these three points for 1873 and 1874:

Date.	Stage of Cairo.	Stage of Helena.	Mean of Cairo and Helena.	Stage of Memphis.	Mean Cairo and Helena minus Memphis.	Remarks.
October, 1873	3'.95	4'.05	4'.0	2'.9	1'.1	No swamp discharge.
November, 1873	13'.8	12'.4	13'.1	8'.4	4'.7	Do.
January, 1874	12'.9	13'.5	13'.2	8'.6	4'.6	Do.
January, 1873	24'.0	23'.0	23'.5	18'.2	5'.3	Do.
December, 1873	34'.48	33'.50	34'.0	27'.8	6'.2	Do.
March, 1874	45'.0	42'.4	43'.7	34'.4	9'.3	Large swamp discharge.
May, 1874	48'.37	45'.82	47'.1	35'.0	12'.1	Do.

These are plotted on same sheet, and give a *curve* below line of overflow, whereas the stages taken in 1881 and 1882 seemed to give a straight line below the line of overflow. The curves show, however, that for a given stage at Cairo and Helena the stage at Memphis has lowered about 2 feet since 1874. It will be noticed that the two curves come together at a 47 to 48 foot stage at Cairo and Helena. This stage gives a general overflow of the Saint Francis bottoms, which acts as an equalizer on the slope from Cairo to Helena, and therefore the Commerce Cut-off does not affect it.

By continuing the curve above the point of overflow, with the same bearing as it has below this point, we get the effect of the overflow into the Saint Francis in depressing the river surface at Memphis.

According to this the river was 3.3 feet lower at Memphis than it would have been if no water had escaped into the Saint Francis. This, however, is for a mean stage at Cairo and Helena of 50 feet. If the water had been confined to the channel from Cairo to Helena, the stage would have been much higher at each point, and each about the same height, and the stage at Memphis correspondingly increased. This should be studied in connection with other gauges between Cairo and Helena. I have not had time to pursue this subject farther.

As to the sources of the flood, the curves plotted show that it must have been from the Ohio, White, and Arkansas, together with the Saint Francis and Yazoo. The stage at Saint Louis was very low until February 19, when it rose 16 feet in two days—a rise wholly unprecedented, I believe, for this locality. It went down immediately, however, and did not contribute much to the flood. The White and Arkansas rivers rose at the same time from an 8-foot stage to a 31 and 26 foot stage respectively, reaching their maximum discharge about February 26. These latter were the direct cause of the breaking of the levees in the vicinity of their mouths and below, for the second Helena rise did not reach that locality till about ten days later. Most all the levees in this vicinity broke February 28 and March 1, whereas the second Helena rise did not arrive till March 5 to 8.

I have not investigated for the sources of the flood above Cairo on the Ohio.

The effects of the large breaks on the Yazoo front are very marked on the gauge curves, both above and below. The break at Riverton occurred March 1, and that at Bolivar February 28; the former between the mouths of White and Arkansas, and the latter 26 miles farther down. The fall on the Arkansas City gauge, 30 miles below Bolivar, on March 1 was 1 foot, and the gauge at the mouth of White River 0.4 foot, where each had been rising 0.2 per day. This was wholly due to the two Bolivar breaks. These breaks are almost exactly midway between these two gauges. The effect on the lower gauge was three times as much as that on the upper gauge. (See gauge curves, Plate I.) There were no other breaks on that day below White River except on Catfish Point, a series of small breaks, discharging only about 10,000 cubic feet. The break at Mound Place had occurred February 19, so it does not enter as a new cause on the 28th to March 1. The Bolivar breaks, therefore, seem to be alone responsible for these two sudden changes of stage, with the above result. The total fall in five days, February 28 to March 4, at Arkansas City was 1.6 feet, while at mouth of White River it was but 0.9 foot, and this with the Riverton break, 3 miles below White River, discharging about 100,000 cubic feet, which broke March 1.

The reason of this is probably, that at White River the Arkansas swamps were, at this stage, a part of the river reservoir, and a given outlet would not lower the river so much as it would at Arkansas City, where the channel limits were well defined.

Another well marked case is in the Point Lookout, Lake Providence, and Vicksburg curves, on March 21, where the sudden fall is the result of the Alsatia breaks on the Louisiana side at 4 a. m. of that day. I visited these breaks at 10 a. m. on the 21st, and I estimated then that there was a mile of levee gone. This levee was built in the summer of 1881, the upper portion being about 15 feet high, but on the night of the 20th the water had gone over the whole of it, and would have washed the levee out for many miles had not the breaks relieved it. At 10 a. m. the river had fallen 2 feet at the levee, which was about a quarter of a mile or less from the river bank, and no obstructions intervening. The depth of water in front of the upper breaks was 14 feet. The velocity through these breaks, as the water approached the line of the levee, was about 10 feet per second. The fall through the levee was 7 feet. I could not make any very accurate observations, as it was dangerous to go near them in a skiff. I walked down the levee to the first one and got these estimates:

The discharge, however, was about 100,000 cubic feet per second; the fall at Point Lookout, 10 miles above, was 1.6 feet in one day; at Lake Providence, 21 miles above, it was 1 foot in one day; at Vicksburg, 40 miles below, the fall was 0.5 foot in one day; at all these points the river had been rising uniformly about 0.1 foot per day. (See curves, Plate I.)

It is unfortunate that none of these large breaks occurred in the near vicinity of an observation party. As it is, no data has been obtained bearing directly on the checking of the current and corresponding shoaling up below a large outlet. The breaks at Riverton and Bolivar and those in Thompson Bend, below Alsatia, furnish the finest opportunities for such investigations, above Vicksburg.

The surveys made last winter could hardly be taken as the status just previous to the breaks, for the long continued high water had doubtless materially changed the river-bed at most all points, since the soundings were taken. The results of the observation parties, however, should be studied in this connection.

HEIGHT OF FLOOD FOR A CONFINED CHANNEL.

From a careful study of the plotted gauge curves (Plates I and II), one can form some idea of the probable height of the flood if it had been confined by levees from Cairo down. It is seen from Plate II, Fig. 1, that the November-December rise, which came nearly to the top of the bank, passed from Cairo to Vicksburg, with slight addition of volume from White and Arkansas rivers, and a corresponding additional stage of 1 to 2 feet below these rivers. Using this wave as an argument, we may say that a higher wave, had it been equally confined and correspondingly increased from the White and Arkansas, as this flood was, it would have followed the same course.

Assuming that a confined channel at Cairo would have raised the river there 3 feet, which is Humphreys and Abbot's estimate, we may use the stage of 55 feet as our initial wave and now follow its course down the river. When we consider that this flood was largely increased at maximum stage by the local rainfall below Cairo, we may say that the natural drainage of the Saint Francis would have made at least as high a stage at Helena as at Cairo. This would raise the water at Helena from a 47 to a 55 foot stage—an increase of 8 feet.

From the curve on Plate II, Fig. 2, showing relation of Memphis stage to Cairo and Helena, we would have a stage 12 feet less at Memphis or a 43-foot stage, which would be an increase over this flood of 7 feet.

From the gauge curves for White and Arkansas rivers, Plate I, we see that a large volume of water was added to the Mississippi at the height of the flood. The No-

vember rise of 8 feet in the Arkansas, Plate I, caused the November rise at mouth of White River to be 2 feet higher than at Helena. The great rises of 17 and 24 feet in the Arkansas and White rivers respectively, at the top of the flood, would, I think, have raised the river there at least 3 feet. Allowing for a flattening out of the flood wave of 1 foot from Helena down to White River, we would have a 57-foot stage here, where there was but a 48-foot, an increase, therefore, of 9 feet.

The Yazoo natural discharge would have again added to the flood at nearly its maximum, and therefore probably kept the stage up to 57 feet at that point, making an increase there of 7 feet. It will be seen the December rise was nearly the same at White River and Vicksburg. At Lake Providence, the top of the December rise was 3 feet below that at White River and Vicksburg. If we say it would have been four feet lower for the highest flood, it would have given a 53-foot stage, whereas the highest stage reached was 42 feet, an increase, therefore, of 11 feet.

From this line of argument, therefore, I conclude, that the probable increased height of this flood for the Yazoo Front for a river completely leveed below Cairo, would be something about as follows: Memphis, 7 feet; Helena, 8 feet; mouth of White River, 9 feet; Arkansas City, 9 feet; Lake Providence, 11 feet; Vicksburg, 7 feet.

All this, it must be remembered, is for an assumed stage of 55 feet at Cairo and a confined channel from there down. My impression is, however, that for a confined river at Cairo, the increased rise for this flood would have been greater than 3 feet. It is of course very probable that these excessive stages would gradually be diminished as successive floods which ordinarily caused general overflow, were confined to the channel, thereby increasing, in the course of years, the discharging capacity of the river.

It is also well known that if the river had been confined below Cairo the front part of the flood-wave would have been safely transported to the Gulf, instead of being impounded in the swamps, to be poured back into the channel at the highest stage. The discharge per second would in this case not have reached the proportions attained this year. But if the Yazoo and the Tensas bottoms should be leveed out and the Saint Francis left open for a long high stage at Cairo the effect would be the same as it was in this flood, and the volume of water escaping from the river channel per second into the Yazoo and Tensas bottoms should be added to what passed in the channel to find the amount the channel would have carried per second if no water had escaped, allowance being made for an increased velocity for a higher stage.

The results obtained by the observation parties at Columbus, Helena, Lake Providence, and Red River should furnish data which, when combined with the flood discharge which has passed by these stations, would enable one to reach this subject from another direction.

The observation party will determine:

(1) The area of cross-section at maximum stage; (2) the mean velocity at maximum stage; (3) the increment of mean velocity for each foot rise; (4) the rate of scour on section for each foot rise.

Knowing the area and mean velocity, we, of course, have the discharge. Then, if—

A=area of cross-section at maximum stage;
v=mean velocity at maximum stage;
Q=discharge in cubic feet per second at maximum stage;
A'=new area of cross-section for confined channel;
v'=mean velocity for confined channel;
Q'=discharge for confined channel;
w=width of section for confined channel;
i=increment of mean velocity per foot rise;
r=rate of scour on section per foot rise in square feet;
Δh=additional height for confined channel,

we have—

$$Q=Av \qquad Q'=A'v' \qquad v'=v+i\Delta h \qquad A'=A+\Delta hw+hr.$$

Therefore.

$$Q'=Av'=(A+w\Delta h+r\Delta h)\,(v+i\Delta h)=Av+vw\Delta h+vr\Delta h+Ai\Delta h+iw\Delta h+ir\Delta h^2.$$

But $Av=Q$. Transposing the terms in Δh and dividing by the coefficient of Δh^2, we have—

$$\Delta h^2+\Delta h\left(\frac{v(w+r)+Ai}{i(w+r)}\right)=iw+\frac{Q'-Q}{ir}$$

From which we get—

$$\Delta h=\sqrt{iw+\frac{Q'-Q}{ir}+\frac{1}{4}\left(\frac{v(w+r)+Ai}{i(w+r)}\right)^2}-\frac{1}{2}\left(\frac{v(w+r)+Ai}{i(w+r)}\right)$$

In which the only unknown quantities are Q' and Δh. If the swamp discharge past the station, or rather the amount escaping from the river above the station, is approximately known, this is the $Q'-Q$; and Δh becomes known.

The only data available now for such a computation of this flood are those obtained at Red River Landing, and here we have but the field computations. Taking these, however, and applying this formula to the facts found there, we can at least indicate a method which, I think, may be found of some importance.

To find the rate of scour on the section there has been subtracted from the daily observed areas the area due to increased stage, and the remainder gave the daily scour. The continued summation of these quantities from December 16 to March 31 gave the total scour from the initial date, which was plotted in connection with the gauge reading on Plate IV, Fig. 3. The rate of scour seems to change with the stage, so the mean line is evidently a curve. Assuming, however, that the rate remains constant above 45 feet, and drawing a tangent to the curve at this upper portion (see red dotted line on sheet), we obtain the probable rate of scour for this stage of the river. This is 2,300 square feet per foot rise. The rate of increase of mean velocity was obtained in a similar manner, and was found to be 0.1015 foot per foot rise. The maximum discharge was 1,600,000 cubic feet per second. I think that the entire discharge across the latitude of Red River was about 2,200,000 cubic feet.

The area of cross-section at maximum discharge was 235,360 square feet; the width was 3,900 feet; the stage was 48.32 feet; the mean velocity was 6.78 feet per second. We have, then, for Red River Landing—

$$Q=1{,}600{,}000;\ Q'=2{,}200{,}000;\ A=235{,}360;\ v=6.78 \text{ feet};\ w=3{,}900 \text{ feet};$$
$$h=48.32 \text{ feet};\ i=0.1 \text{ foot};\ r=2{,}300 \text{ square feet}.$$

From which, according to the above formula—

$$\Delta h=8.5 \text{ feet}.$$

This is for a confined channel, with the Atchafalaya closed, and the most uncertain element in the problem is whether or not the scour would have continued at the same rate for this increase of stage. If the rate of scour should increase with a higher stage, the increase of flood height here would be less than 8.5 feet. If the rate should continue as it is here used, the total increase of scour for this additional 8.5-feet rise would be $8.5 \times 2{,}333 = 19{,}830$ sq. feet. The width being 3,900 feet, this would give a scour over the entire cross-section of about six feet. It is probable, however, that the scour would not extend over more than 3,000 feet, which would give a scour of 6.6 feet. The increased velocity would be $6'.78+(8.5\times 0.1)=7'.63$ per second $=5.23$ miles per hour.

The result, therefore, of turning all the river down the Mississippi below Red River, and confining it to the channel, would appear to have been for this flood:

An increase of stage of 8.5 feet; a scour of bed of 6.6 feet; an increase of mean velocity of 0.85 feet.

Such a line of argument could evidently be followed at every point where an observation party has been located.

Most of the results given in the latter part of this report are only supposed to be approximate, and are given rather as indicating a method of approaching some problems than as furnishing their solution.

The total discharge of 2,200,000 cubic feet per second at Red River is only assumed as an extreme limit, and is probably much larger than would have been found at any locality for this flood for a confined channel. It was only taken to show what the argument would lead to for a very extreme case.

Without entering into any discussion of the question, I wish here to state that my judgment is that the most efficient means of passing a large flood from Cairo to the Gulf, with a minimum stage, is by means of cut-offs, judiciously made. I think it is a mistake to say that the result of a cut-off is to raise the stage of water below. After the first rush of water, which gives an *increased discharge* below, I see no reason why the stage below should be raised. I think experiments might be made on a small scale, which would throw considerable light on this question.

Very respectfully, your obedient servant,

J. B. JOHNSON,
United States Assistant Engineer.

First Lieut. SMITH S. LEACH,
Secretary Mississippi River Commission.

Discharge of outlets from Mississippi into the Yazoo Bottom.

Locality.	Kind of outlet.	Date of break.	Date of observation.	Stage of water below maximum.	Width.	Mean depth.	Surface velocity per second.	Discharge per second.	Partial summation of discharge.	Combined summation of discharge.
		1882.	1882.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Cubic feet.*		
1. South Horn Lake	Crevasse*	Mar. 5	Mar. 13	0.5	150	3	3	945	945	
2. Harcklerodes to Star Landing, 3.5 miles	Over bank†	Jan. 20	Mar. 14	0.5	5,000	2	1.5	10,500		
	Do	Jan. 20	Mar. 14	0.5	2,300	3	1.5	7,245		
	Do	Jan. 20	Mar. 14	0.5	1,000	1.5	1	1,050		
	Do	Jan. 20	Mar. 14	0.5	1,000	1.5	2	2,100	20,895	
					9,300					21,840
3. Commerce to Mhoon's Landing, 10 miles	Crevasse‡	Mar. 5	Mar. 14	0.5	600	3.5	2	2,940		
	Do	Mar. 5	Mar. 14	0.5	120	5	4.5	1,890		
	Do	Mar. 5	Mar. 14	0.5	240	4	3.5	2,350		
	Over levee		Mar. 14	0.5	450	1	3.5	1,100		
	Do		Mar. 14	0.5	120	1	3.5	300		
	Do		Mar. 14	0.5	80	1	4.5	250		
	Do		Mar. 14	0.5	100	1	3.5	245		
	Do		Mar. 14	0.5	2,600	0.5	4	3,640		
	Crevasse	Mar. 5	Mar. 14	0.5	60	3	4.5	570		
	Do	Mar. 5	Mar. 14	0.5	200	3	5	2,100		
	Do	Feb. 12	Mar. 14	0.5	900	3	5	9,450		
	Do	Feb. 12	Mar. 14	0.5	200	4	5	2,800		
	Do	Mar. 5	Mar. 14	0.5	150	5	5	2,550		
	Do	Mar. 5	Mar. 14	0.5	150	4	5	2,100		
	Do	Mar. 5	Mar. 14	0.5	100	5	5	1,750		
	Do	Mar. 5	Mar. 14	0.5	50	3	5	525		
	Do	Mar. 5	Mar. 14	0.5	150	3	5	1,575		
	Do	Mar. 5	Mar. 14	0.5	500	3.5	5	6,125		
	Do	Mar. 5	Mar. 14	0.5	120	6	6	3,020		
	Do	Mar. 5	Mar. 14	0.5	75	2	4	420		
	Do	Feb. 12	Mar. 14	0.5	360	9	3	5,670		
	Do	Feb. 12	Mar. 14	0.5	200	8	3	3,360		
4. In vicinity of Mhoon's Landing	Crevasse	Feb. 12	Mar. 14	0.5	30	6	3	380		
	Do	Feb. 12	Mar. 14	0.5	900	7	3.5	15,435		
	Do	Feb. 12	Mar. 14	0.5	2,100	8.5	3.5	43,730		
	Do	Feb. 12	Mar. 14	0.5	260	8	6	8,870		

	Do	Feb. 12	Mar. 14	0.5	165	3	3	1,040	124,185	
					11,510					146,025
5. Mhoon's Landing to McKinney Bayou, 7 miles (flow back to river).	Over levee§	Feb. 16	Mar. 15	0.4	2,500	0.5	1.5	1,310		
	Do	Feb. 16	Mar. 15	0.4	2,500	1	2	3,500		
	Crevasse	Feb. 16	Mar. 15	0.4	660	5	3	6,930		
	Over levee	Feb. 16	Mar. 15	0.4	1,000	1	2	2,240		
	Do	Feb. 16	Mar. 15	0.4	500	2	3	2,100		
	Do	Feb. 16	Mar. 15	0.4	660	1	2	920		
	Crevasse	Feb. 16	Mar. 15	0.4	500	5	3	5,250		
	Do	Feb. 16	Mar. 15	0.4	660	2.5	5	5,500		
	Do	Feb. 16	Mar. 15	0.4	330	3	5	3,400		
	Overflow	Feb. 16	Mar. 15	0.4	330	1	4	920		
	Over levee	Feb. 16	Mar. 15	0.4	330	1	2	460		
	Do	Feb. 16	Mar. 15	0.4	500	1	2	700		
	Do	Feb. 16	Mar. 15	0.4	660	1	1	460		
	Do	Feb. 16	Mar. 15	0.4	330	1	3	700		
	Crevasse	Feb. 16	Mar. 15	0.4	165	2	5	1,150		
	Do	Feb. 16	Mar. 15	0.4	165	3	5	1,730		
	Do	Feb. 16	Mar. 15	0.4	660	2	3	2,770		
	Do	Feb. 16	Mar. 15	0.4	500	3	6	6,300		
	Over levee	Feb. 16	Mar. 15	0.4	660	1	3	1,400		
	Crevasse	Feb. 16	Mar. 15	0.4	330	2	3	1,400		
	Over levee	Feb. 16	Mar. 15	0.4	330	1	3	700		
	Crevasse	Feb. 16	Mar. 15	0.4	330	2	3	1,400		
	Over levee	Feb. 16	Mar. 15	0.4	330	1	3	700		
	Do	Feb. 16	Mar. 15	0.4	660	1	3	1,400		
	Crevasse	Feb. 16	Mar. 15	0.4	165	2	3	700		
6. McKinney Bayou	Crevasse	Feb. 18	Mar. 15	1.1	324	13	3.5	10,320	—64,360	
					16,680					81,665
7. McKinney Bayou to Austin (2¼ miles)	Over levee	Feb. 14	Mar. 15	1.1	660	1	1	460		
	Crevasse	Feb. 14	Mar. 15	1.1	310	‖32	2.25	10,400		
	Over levee	Feb. 14	Mar. 15	1.1	330	1	2	460		
	Do	Feb. 14	Mar. 15	1.1	330	1	1.5	350		
	Do	Feb. 14	Mar. 15	1.1	330	1	3	700		
(Flow from river)	Crevasse	Feb. 17	Mar. 15	1.1	412	‖27	3	15,600		
	Over levee	Feb. 14	Mar. 15	1.1	330	1	1	230		

* Data obtained of J. P. Thurman, of Norfolk Landing.
† Water has been escaping over this bank since January 25, the stage at Memphis having varied but 2 feet since then.
‡ These breaks commence about 3 miles below Commerce, and continue to about three-quarters of a mile below Mhoon's. Depth of overflow on cultivated fields back of Mhoon's, about 8 feet.
§ The overflow from 2 miles below Mhoon's to McKinney Bayou is back into river. It will be seen, comparing amounts, that the water that flows back to the river above McKinney Bayou all went in above Mhoon's Landing.
‖ Only two-thirds of these sections considered available for discharge; the rest is eddy. Greatest depth is 48 feet.

Discharge of outlets from Mississippi into the Yazoo Bottom—Continued.

Locality.	Kind of outlet.	Date of break.	Date of observation.	Stage of water below maximum.	Width.	Mean depth.	Surface velocity per second.	Discharge per second.	Partial summation of discharge.	Combined summation of discharge.
				Feet.	*Feet.*	*Feet.*	*Feet.*	*Cubic feet.*		
7. McKinney Bayou to Austin (2½ miles)—Continued. Flow from river—Continued.	Crevasse	Mar. 5	Mar. 15	1.1	360	*15	3	11,340		
	Do	Mar. 5	Mar. 15	1.1	115	2	5	800		
					3,177				40,340	122,005
8. Austin to Glendale (20 miles)	Crevasse	Mar. 5	Mar. 16	1.2	500	2	2	1,400		
	Do	Mar. 5	Mar. 16	1.2	260	4	3	2,170		
	Do	Mar. 5	Mar. 16	1.2	60	4	4	660		
	Do	Mar. 5	Mar. 16	1.2	80	6	4	1,340		
	Do	Mar. 5	Mar. 16	1.2	50	5	2	350		
9. Back of Sunflower Lake	Crevasse	Mar. 5	Mar. 16	1.2	50	3	4	420		
	Do	Mar. 5	Mar. 16	1.2	725	†47	2	47,770		
	Do	Mar. 5	Mar. 16	1.2	....	30	3			
	Do	Mar. 5	Mar. 16	1.2	330	10	3	6,930		
	Do	Mar. 5	Mar. 16	1.2	75	12	2	1,260		
	Do	Mar. 5	Mar. 16	1.2	1,650	2	1	2,300		
	Do	Mar. 5	Mar. 16	1.2	130	8	2	1,470		
	Do	Mar. 5	Mar. 16	1.2	60	6	2	550		
	Do	Mar. 5	Mar. 16	1.2	100	12	2	1,680		
	Over levee	Feb. 10	Mar. 16	1.2	1,000	1	2	1,400		
	Crevasse	Feb. 10	Mar. 16	1.2	200	6	4	3,360		
	Over levee	Feb. 10	Mar. 16	1.2	660	1	1.5	700		
	Crevasse	Feb. 10	Mar. 16	1.2	200	10	4	5,600		
	Do	Feb. 10	Mar. 16	1.2	230	9	3	4,350		
	Over levee	Feb. 10	Mar. 16	1.2	1,000	1	1	700		
	Crevasse	Feb. 10	Mar. 16	1.2	330	5	6	6,930		
	Do	Feb. 10	Mar. 16	1.2	660	3	3	4,160		
	Do	Feb. 10	Mar. 16	1.2	330	2	3	1,390		
	Do	Feb. 10	Mar. 16	1.2	165	16	1	1,850		
	Over levee	Feb. 10	Mar. 16	1.2	330	1	2	460		
	Do	Feb. 10	Mar. 16	1.2	330	1	1	230		
	Crevasse	Feb. 10	Mar. 16	1.2	330	3	2	1,400		
	Do	Feb. 10	Mar. 16	1.2	165	32	1	3,700		
	Over levee	Feb. 10	Mar. 16	1.2	330	1	4	920		
	Do	Feb. 10	Mar. 16	1.2	330	1	1	230		
	Crevasse	Feb. 10	Mar. 16	1.2	165	4	5	2,310		
	Over levee	Feb. 10	Mar. 16	1.2	1,320	2	4	7,400		

	Do	Feb. 10	Mar. 16	1.2	1,320	2	4	7,400		
	Crevasse	Feb. 10	Mar. 16	1.2	100	10	6	4,200		
10. Trotter's Landing	Levee caved off in December	Jan. 15	Mar. 16	1.2	700	10	4	19,600		
	Over levee	Feb. 10	Mar. 16	1.2	330	1	3	*700		
	Do	Feb. 10	Mar. 16	1.2	200	2	3	*840		
	Do	Feb. 10	Mar. 16	1.2	165	2	4	*920		
	Do	Feb. 10	Mar. 16	1.2	200	1	2	*420		
11. Just above railroad	Crevasse	Feb. 10	Mar. 16	1.2	260	25	4	†18,200		
					15,420				167,670	289,675
12. Glendale to foot Island 64 (85 miles)	Two crevasses	Mar. 6	Mar. 17	1.2	700	5	6	14,700		
	Crevasse	Feb. 12	Mar. 17	1.1	660	11	8	§40,650		
	Do	Feb. 9	Mar. 17	1.1	300	10	6	12,600		
13. 6 miles below Friar's Point	Crevasse	Feb. 10	Mar. 17	1.1	2,000	4	5	28,000		
	Do	Feb. 10	Mar. 17	1.1	65	6	2	550		
	Do	Feb. 10	Mar. 17	1.1	660	6	4	11,100		
	Do	Feb. 10	Mar. 17	1.1	330	4	4	3,700		
	Do	Feb. 10	Mar. 17	1.1	660	4	4	7,400		
14. Opposite Island No. 63	Crevasse	Feb. 10	Mar. 17	1.1	330	2	3	1,400		
	Do	Feb. 10	Mar. 17	1.1	660	4	4	7,400		
	Do	Feb. 10	Mar. 17	1.1	330	4	4	3,700		
	Do	Feb. 10	Mar 17	1.1	330	4	4	3,700		
	Do	Feb. 10	Mar. 17	1.1	990	4	3	8,320		
	Do	Feb. 10	Mar. 17	1.1	330	4	4	3,700		
	Do	Feb. 10	Mar. 17	1.1	65	6	2	550		
	Do	Feb. 10	Mar. 17	1.1	330	3	2	1,400		
	Do	Feb. 10	Mar. 17	1.1	330	4	3	2,770		
	Do	Feb. 10	Mar. 17	1.1	500	4	3	4,200		
	Do	Feb. 10	Mar. 17	1.1	500	2	6	4,200		
	Do	Old br'k.	Mar. 17	1.1	400	9	3	7,560		
15. Bland's Bayou (old break)	Levee caved off	Old br'k.	Mar. 17	1.1	3,300	4	1	9,240		
					13,070				176,840	466,515
16. Above Sunflower Landing	Crevasse	Old br'k.	Mar. 18	1.2	20	3	3	‖400		
	Over bank	Old br'k.	Mar. 18	1.2	10,500	5	1	36,750		
					10,520				37,150	429,365
17. Sunflower to mouth of White River	Crevasse	Mar. 5	Mar. 18	1.2	330	4	3	4,160		
18. Lake Charles	Crevasse	Mar. 5	Mar. 18	1.2	580	4	3	3,640		
	Do	Mar. 5	Mar. 18	1.2	80	4	3	520		
	Do	Mar. 12	Mar. 18	1.2	600	5	3	6,300		
19. Pushmataha	Crevasse	Mar. 12	Mar. 18	1.2	165	5	2	1,150		

* Fall through levee, 2.1 feet.

† Sounded two sections. Mean of one, 47 feet; mean of other, 30 feet. The velocity on deep sec. = 2 feet. The velocity on 30-foot sec. = 3 feet. Levees, 50 feet from Sunflower Lake. A deep gorge cut out clear from lake. Deepest water, 60 feet.

‡ These breaks on Thompson place below Glendale. Data obtained from Captain Stancell, of Helena, levee contractor.

§ This break 1½ mile above Delta. Fall through levee, 30 inches; velocity so rapid could not go near it with skiff. Average depth where soundings could be taken was 11 feet.

‖ Levee caved off for 2 miles above Sunflower. Flow back to river.

Discharge of outlets from Mississippi into the Yazoo Bottom—Continued.

Locality.	Kind of outlet	Date of break.	Date of observation.	Stage of water below maximum.	Width.	Mean depth.	Surface velocity per second.	Discharge per second.	Partial summation of discharge.	Combined summation of discharge.
					Feet	*Feet.*	*Feet*	*Cubic feet.*		
19. Pushmataha—Continued	Crevasse	Feb 26	Mar. 18	1.2	400	24	6	*40,320		
20. Concordia	Crevasse	Feb. 28	Mar. 18	1.2	165	6	4	2,800		
					2,320				58,890	488,255
21. Riverton break	Crevasse†	Mar. 1	Mar 18	1.2	1,100	31	4.5	107,400	107,400	595,655
	Do	Mar 1	Mar. 18	1.2	500	4	4	5,600		
22. Riverton to Prentiss (8 miles)	9 crevasses	Mar. 1	Mar. 18	1.2	1,525	4	3	12,810		
23. At Hughes	Crevasse	Mar. 1	Mar. 18	1.2	660	5	6	13 860		
					3,785				32,270	627,925
24. Just above Bolivar	Crevasse‡	Feb. 28	Mar. 19	2.2	550	30	3.5	‡37,530		
25. Just below Bolivar	Crevasse‡	Feb. 28	Mar. 19	2.2	600	14	6	35,280		
	Do	Feb. 28	Mar. 19	2.2	1,320	12	5	55,440		
					2,470				128,250	756,175
26. On Catfish Point	do	Feb. 28	Mar. 19	2.2	330	4	4	3,500		
	2 crevasses	Feb. 28	Mar. 19	2.2	330	5	2	2,310		
					660				5,810	761,985
(Flow back to river since March 13)	Crevasse	Feb. 28	Mar. 19	2.2	200	3	2	840	840	761,145
72. At Mound Place	Crevasse	Feb. 19	Mar. 19	2.2	410	18	4	20,660	20,660	781,805

* Levee here crosses Concordia Bayou. Soundings on line of levees as great as 48 feet. Depth of water in bayou 28'.
† A gorge cut out from river bank clear through levee.
‡ These two are one break. The deep section is where levee broke before. Deepest soundings 48 feet in deep section.

2.—SAINT FRANCIS FRONT, FOR THE FLOOD OF 1882.

(By Hunter Stewart, United States Assistant Engineer.)

SAINT LOUIS, MO., *July* 25, 1882.

SIR: I have the honor to submit herewith my report on the examination of the inundation of the Saint Francis front, made in accordance with your instructions of March 7, 1882.

Very respectfully, your obedient servant,

HUNTER STEWART,
United States Assistant Engineer.

First Lieut. SMITH S. LEACH,
Secretary Mississippi River Commission,
No. 2828 *Washington avenue, Saint Louis, Mo.*

JOURNAL.

The party left Saint Louis at 2 p. m., on March 7, 1882, on board of the steamer R. J. Wheeler, which had been assigned to them. Commerce, Mo., the upper limit of the front of the Mississippi River that is tributary to the Saint Francis Bottom, was passed at 12.30 p. m. on March 8. The banks of the river between Commerce and Dog-Tooth Island were either altogether out of water or barely covered. When the Missouri Sister Island was reached some overflow was found, but the water of the same was slack. The current in the Mississippi River itself slackened considerably as Cairo was approached. Some twelve examinations were made in the 12 miles between Able's Point and Cairo, but no current of any importance was found. the little that there was, 6 to 8 feet per minute, being generally either parallel with or towards the river. Cairo was reached on the evening of the 8th. On the morning of the 9th we left Cairo at 7.30 a. m., proceeding down the river. The bank of Bird's Point was exposed. We went as far as Norfolk, Mo., finding but slight current, and that was generally in the direction of the river. At 10 a. m., the rain having ceased, the wind rose and became so high as to affect the surface velocity to such an extent as to render the indications of the log unreliable. The storm continuing all day no more work was done. On March 10 the right bank was examined from Norfolk, Mo. to Point Pleasant, Mo. The New Madrid Ridge was uncovered, although it had been submerged, and a great amount of water was returning to the river between it and Donaldson's Point.

On March 11 the right bank was examined from Point Pleasant to Daniel's Point, the greater part of this stretch being submerged, and on the left bank current observations were made at the mouths of the Obion, the Upper and Lower Forked-Deer rivers.

March 12. In the morning the right bank was examined from Daniel's Point to Osceola, Ark.; arrived at Plum Point at 8.30 a. m.; left at 2.30 p. m.; the steamer R. J. Wheeler having been used during this interval in getting ready the outfit for the reconnaissance of the Saint Francis Bottom by Assistant Engineer E. S. Davis, who had come aboard at Cairo. During the afternoon of the 12th the right bank was examined from Osceola to the upper portion of the bend of Island No. 35.

March 13. The right bank was followed closely, through the bend of Island No. 35, McGavock's Chute, the bend of Island No. 37, Devil's Elbow Bend, Fogleman's Chute, Beef Island Bend, Redman's Point, up the chute of the Chicken Island, back again, and thence to Hopefield. Memphis was reached at 1.30 p. m.; instructions were telegraphed for, and reply arrived at 9 p. m.

March 14. The right bank was examined from Hopefield to the lower end of Commerce Cut-off, including Council Bend.

March 15. The right bank was examined from Commerce Cut-off to the upper end of Saint Francis Island. I proceeded thence to Helena, and telegraphed for instructions; returned to the upper end of Saint Francis Island, examined the bank on the up-trip, finished reconnaissance, and returned to Helena.

THE MODE OF OBSERVING.

The steamer kept as close to the right bank of the river as the nature of the shore would permit. Observations were made in a skiff, which had to be carried aboard in order to prevent its swamping. When it had been decided to take an observation the steamer would slacken speed and reverse her engines, the skiff would be launched, and the observing party push out to the shore. When this was reached the skiff was made

fast, a sounding taken, and the surface velocity measured by means of the log, and its direction with a prismatic compass. The skiff was then cast loose and rowed some distance over the bank, the leadsman taking soundings, and if any marked change in depth was found, a greater distance would be sounded and the mean of the soundings recorded. The steamer in the meanwhile would stem the current with her head down-stream, or, if that were impossible on account of the wind or the great velocity of the current, she would round-to after the skiff was launched and would again round-to when the latter put out from shore, so as to be ready to proceed down-stream as soon as the skiff was hauled aboard.

Whenever the banks were submerged for a great distance, which was generally the case, and they could be seen from the boat, an observation would be made after a five minutes' run, that being the estimated length of time required for the Wheeler to go a mile down-stream. This would sometimes be varied by the observer watching from aboard the steamer the direction and velocity of the current over the bank as shown by the break of the water against the timber, and selecting localities for observation where it appeared to him to be a mean for a given stretch; he estimating what proportion of the distance between two observations should be applied to each.

Where submerged and exposed banks alternated, the depth and velocity of the surface water would be measured as above, the length of the overflowed bank would be estimated, and the location of the point of observation and limits of overflow noted, the distances being afterwards taken off of the detail charts in the office.

In the case of open streams a cross-section would be sounded, the soundings being placed approximately equidistant, and the surface velocity measured, where possible; otherwise it would be estimated.

The locality of the observation was in every instance noted, and as soon as the observer returned to the steamer, plotted as closely as possible from the information given by the pilots and the character of the topography—Major Suter's reconnaissance was used between Cairo and Memphis and between Commerce Cut-off and Helena, and General Comstock's detail charts between Memphis and Commerce Cut-off.

The river bank proper, in contradistinction to the artificial bank or levee, was examined throughout, and no effort was made to follow the latter, as neither a greater nor a less amount of water than the net escape over the bank could get into the back country. It is evident that, providing the examination of the movement of the water on the bank was correctly and accurately made, the results of such a method would be the same as those obtained from a correct and accurate examination of the line of levees. Even supposing that there is a greater probability of error in the former than in the latter method, still the increased accuracy that would have resulted from following the remnants of the levees, being such a small percentage of the total amount, would not have justified the use of the greater length of time that would have been required.

For in the length of river front included in the right bank between Commerce, Mo., and Helena, Ark., the system of levees is very imperfect, the percentage of unleveed bank being very large, and, as by far the greater part of the total amount of outflow and inflow occurs over the latter portion, it would have been necessary to apply to it the same method of observation as was used over the entire stretch. Moreover, where there were levees, they would virtually exclude a corresponding length of river front from the computation, either by deflecting the current of the overflow so as to cause its direction to become parallel with that of the river, or by checking it so as to render the intervening water slack.

REDUCTION.

As the examination was made after the crest of the flood-wave had passed, the discharge obtained from the observations had to be corrected for difference of stage in order to estimate the discharge at the maximum and at the mean flood stage. The data obtained were crude in their nature, and no attempt at a very refined reduction of them has been made; but when a method had been decided upon, it was rigorously carried out in order to secure accuracy of computation. This fact will account for the seemingly unwarranted exactness of the tabulated results.

The following formulæ were used in computing discharge:

For observation stage—

$$Q = V \times W \times S \times C;$$

wherein—

$Q =$ discharge.
$V =$ surface velocity.
$W =$ width of cross-section.
$S =$ sounding.
$C =$ coefficient of reduction, which is the product of the coefficient to convert surface velocity into mean velocity, and the coefficient to correct cross-section area for obstructions.

For maximum stage—

$$Q = V \times W \times D \times C$$

wherein—

V, W, and C are the same as above.
D = computed depth at highest stage.

For mean flood stage—

$$Q = V \times W \times D \times C$$

wherein—

V, W, and C are as above.
D = computed depth at mean flood stage.

The reasons for using the above elements of discharge are given further on.

VELOCITY.

Velocity may be regarded as a function of slope and mean depth.

1. Regarded as a function of slope.

It may be premised that, when the swamps are filled, the oscillation of the river is identical with that of the escaping water in its immediate vicinity and the slope remains constant.

The following facts may be quoted in substantiation of the above statement.

The high-water reconnaissance of the Saint Francis Basin, March, 1882, by Assistant Engineer E. S. Davis, shows that the observed water surface and the surface of the highest water, as given by high-water marks, were sensibly parallel.

Observations were made near Commerce, Miss., during the month of February, 1882, to determine the amount of fall in the river that would be necessary to uncover a tract of submerged land which was separated from the river by a strip of exposed land and a levee—the overflow being caused by back-water from breaks in the levee farther down the river. One gauge was placed in front of the levee and another in the overflowed field back of it, and the latter showed a responsive and almost identical change with the former.

Therefore, in so far as velocity is the result of slope, it is just to conclude that the velocity of the water escaping over the banks of the river will remain nearly constant after the movement of the water in the adjacent swamp has reached its normal relation with the river; that approximating equilibrium.

2. Regarded as a function of mean depth.

For a discharging channel an increased mean depth generally produces a decreased ratio of friction to cross-section area and a resulting greater velocity; but, as in the case of inundated lands, where the principal cause of friction is the obstructions in the channel, it is easy to conceive of circumstances, such as the flood reaching the branches of the underbrush or of the timber, where the ratio would increase with the mean depth. Therefore, not only does the velocity of the water escaping over the banks not necessarily increase, but it may diminish with an increased mean depth.

Moreover, if to the measured velocities formulæ were applied which had been deduced from data obtained under conditions varying from those found during the examination, or those probable at a higher or a lower stage, the only result that could be attained would be the certainty of a large probable error with an uncertain sign.

Considering all of these circumstances, it was thought that more accurate results could be obtained, in calculating the discharge for highest and mean stages of the flood, by using those velocities measured at an intermediate stage than any that could be obtained from them by computation.

Therefore the observed velocities were used in all discharge calculations.

MEAN DEPTH.

1. *Observed stage.*—The soundings were used.

2. *Maximum stage.*—The depth obtained by sounding has to be increased by the difference between the stage of water at the time of observing and the highest stage, in order to obtain a depth that can be used in the computation of the discharge for the latter.

The most accurate method of attaining the above would have been to have measured the difference between the two stages at every point of observation, provided reliable high-water marks were obtainable. This could be done but seldom, owing to the indistinctness of the marks on the trees, and on account of the necessary

rapidity of the work, which precluded the possibility of going any distance to get a recorded high-water mark. As the accuracy of the differences measured were, in most cases, considered questionable, and as the number of reliable ones was not sufficient to reduce the work, this method was discarded and recourse taken to the gauge records.

Therefore, the increments to convert soundings to mean depth at high water were obtained graphically, by using the records at the gauge stations. The distances along the river were plotted as horizontal co-ordinates; for that portion between Cairo and Memphis, those given on the charts of the Mississippi River Commission were used; and for the portion between Memphis and Helena, those on the charts of Major Suter's reconnaissance; the difference between the mean gauge reading for the date of examination and the highest gauge reading, at each station, were plotted as vertical co-ordinates; and the resulting points were connected by straight lines—the ordinate, corresponding to its distance from Cairo, giving the increment for any intermediate locality.

This method is, of course, open to the objection that the probable oscillation at a point between two measured oscillations is not necessarily proportionate to the distance; but, in the absence of a better one, it was adopted as giving a sufficiently close approximation.

3. *Mean flood stage.*—The mean flood stage being lower than the observed stage, the depths obtained by sounding have to be decreased by the difference between the stages, in order to compute the discharge at the former. In obtaining this, the zero stage, or that at which the escape of water from the river would practically cease, was determined for each gauge from the depth of overflow at the observed stage; the gauge curve was plotted for the time that the river was continuously above this stage, the area of the included surface was measured with the planimeter and the mean height of the curve determined. This height added to the reading of the zero flood stage gives the mean flood stage. The difference between the mean gauge reading at the examination and that for mean flood stage at each station were plotted, and the decrements which were to be applied to the soundings taken at the former were obtained in the same manner as were the increments for maximum stage.

The following are the readings of the zero flood stage on the gauges: Cairo, 41 feet; Columbus, 95 feet; New Madrid, 37 feet; Cottonwood Point, 32 feet; Fulton, 32 feet; Memphis, 29 feet.

Gauge readings, increment and decrements:

CAIRO.

	Feet.
Highest stage, February 26, 1882	51.87
Observed stage, March 10, 1882	47.70
Mean flood stage	46.24
Increment	4.17
Decrement	1.46

COLUMBUS.

Highest stage, February 26, 1882	102.801
Observed stage, March 10, 1882	100.243
Mean flood stage	99.14
Increment	2.558
Decrement	1.103

NEW MADRID.

Highest stage, February 27, 1882	47.5
Observed stage, March 10, 1882	43.7
Mean flood stage	42.2
Increment	3.8
Decrement	1.5

COTTONWOOD POINT.

Highest stage, February 28, 1882	37.5
Observed stage, March 11, 1882	36.3
Mean flood stage	35.62
Increment	1.2
Decrement	0.65

FULTON.

	Feet.
Highest stage, March 1, 1882	36.69
Observed stage, March 12, 1882	36.04
Mean flood stage	35.15
Increment	0.65
Decrement	0.89

MEMPHIS.

Highest stage, March 6 and 9, 1882	35.15
Observed stage, March 13, 1882	34.70
Mean flood stage	33.4
Increment	0.45
Decrement	1.30

MEMPHIS.

Highest stage, March 6 to 9, 1882	35.15
Observed stage, March 14, 1882	34.55
Increment	0.60

MHOON'S LANDING.

Highest stage, March 9, 1882	40.80
Observed stage, March 15, 1882	39.95
Increment	0.85

HELENA.

(Mississippi River Commission gauge.)

Highest stage, March 8, 1882	47.10
Observed stage, March 15, 1882	46.20
Increment	0.90

WIDTH OF CROSS-SECTION.

The width of the cross-section, or, in other words, the length of river front which is o be applied to the computed mean depth, is, to a great extent, a question of personal bservation and judgment.

The positions of the observations were plotted on the small charts and the distances were taken from the detail ones. Whenever there were no indications to the conrary, one-half of the distance between three consecutive observations was applied to he middle one; otherwise the distances were adjusted as the notes or the memory of he observer dictated.

COEFFICIENTS.

The only velocity measured being that of the surface, a reduction to mean velocity s necessary in order to obtain true discharge. As neither the time nor the appliances vere available to determine the relation of surface velocity to the curve of vertical elocities for discharge taking place over the bank of the river, and as no data bearng upon the subject were procurable, the adoption of the coefficients had to be dermined arbitrarily. The acknowledged tendency towards exaggeration, in calcuating flood discharge from meager data, was the one known fact that has indicated he use of as small a coefficient as was warranted by other hydraulic observations. Vith this in view the following coefficients were adopted:

For open streams, mean velocity = surface velocity × .8

For crevasses, mean velocity = surface velocity × .72

For discharge over the banks, mean velocity = surface velocity × .72

.72 being Brüning's smallest coefficient for open channels).

Coefficient for obstructions.—As most of the outflow and inflow was taking place over he banks, and as these were generally covered with vegetation, it is necessary to nake a correction of the measured cross-section in order to obtain the area effective or discharge.

From the general nature of the bank, varying from open fields to a thick growth of young cottonwoods, and in view of the large reduction made in calculating mean velocity, a reduction of 10 per cent. of cross-section area appears to be sufficiently arge.

Effective area = cross-section area × .9.

For discharge over the bank, we have—

$$Q = V \times .72\,(D \times W) \times .9 = V \times D \times W \times .648,$$

or, discarding the last decimal in favor of the nearer hundredth, we have—

$$Q = V \times D \times W \times C$$

where $C = .65$.

RESULTS.

From Commerce, Mo., to a point 14 miles below Cairo, there was no escape from the river. At New Madrid, Mo., there was a net escape, at highest stage, of 86,000 and at observed stage of 20,000 cubic feet per second; at mean flood stage there was no escape. These figures reveal the influence of the New Madrid Ridge, which deflected the overflow water and caused its return to the river, and which was in ratio to its total, partial, or non-submergence—most of the return flow occurring between Donaldson's Point and New Madrid.

From the New Madrid Ridge to Helena there was a continuous overflow, with the exception of that portion of the old bank of the river situated between the foot of Island 35 and Fogleman's Chute, the exposure of the left bank in this locality being, in all probability, the result of the many changes which have occurred in the river in its vicinity.

A point opposite Memphis, Tenn., may be regarded as the limit of supply to the Saint Francis Bottom, as a study of the curve of net escape shows but a slight oscillation from there to a point 28 miles below; at this latter place the return flow commences, and, were the movements over points omitted, the curve would show a continuous decline.

We have at Helena: At maximum stage, a virtual balancing of outflow and inflow; at the observed stage, which was below high water, 3.8 feet at New Madrid and 0.9 feet at Helena, an excess of return flow over the bank of 150,000 cubic feet per second, to which 50,000 cubic feet per second, at the least estimate, should be added for overflow water carried by the Saint Francis River, showing that, at the time that the examination was made, the Saint Francis reservoir was being emptied at the rate of 200,000 cubic feet per second.

AT HIGHEST STAGE.

	Cubic feet per second.
Summation of outflow and inflow	2,440,000
Amount of overflow to be returned by the Saint Francis River	63,000
Total movement	2,503,000
Summation of outflow	1,251,000
Maximum net escape on any one latitude	615,000
Saint Francis River:	
Estimated discharge	115,000
Supply from outflow from Mississippi River	63,000
Supply from other sources	52,000

Classification of outlets.

	Cubic feet per second.	Per cent.
Water escaping in bends	860,000	35
Water returning in bends	833,000	33
Water escaping in reaches and over points	372,000	15
Water returning in reaches and over points	420,000	17
	2,485,000	100
Total movement for bends	1,693,000	....
Total movement for points and reaches	792,000	....
Approximation discrepancy	17,000	....
Total movement	2,502,000	....

	Escape.	Return.
	Per cent.	*Per cent.*
Over the banks of bends	69	56
Through regular channels	1	10
Over the banks of points and reaches	30	34
Total	100	100

We may summarize as follows: A very small percentage of the water that leaves the river passes through regular water-courses; most of the water that, at any time, leaves the river and nearly all of the overflow water that traverses the Saint Francis Bottom, escapes from the river in bends; a major part of the return occurs over the banks in bends; the greater part of the escape over the banks of points, merely crosses these to return a short distance below.

There are three causes—two applying to velocity and one to depth—that would develop expectations of greater escape in the bends than in other portions of the river front: First, on account of the converging angle formed by the directions of the bank of the bend and the current in the river, and a consequent conservation of momentum. Second, on account of the general concavity of bends and the resulting proximity of the deep channel and swift velocity, which is conducive to a greater initial velocity of the escaping water. Third, on account of the relatively lower elevation of the bank in bends as compared with other divisions of the river front; for, as most of the bends have caving banks, the bank-destroying process of the river is operative thereat, and, as the slope of the land is generally from the river, the height of the banks is being constantly reduced. By antithesis, on points the bank-building process is generally active, and the river front is of normal or increasing elevation. We find as a consequence that the depth of overflow is greater in the bends than at other localities.

If the term "marked depressions in the bank" be confined to sloughs and bayous, then a very small percentage of the outflow or of the inflow occurs therein; but if the banks of bends are regarded as such, which they may very properly be considered in their relation to other portions of the river front, then they are the channels for the greater part of the outflow and a major part of the inflow along the Saint Francis Front.

MAXIMUM DISCHARGE.

In order to estimate the entire discharge at high water of the Mississippi River on different latitudes the following localities were selected: Columbus, Ky., Fulton, Tenn., and Hampton discharge section; and estimates made.

COLUMBUS, KENTUCKY.

The discharge at the highest stage, February 26, 1882, not having been measured, the following estimate has been made from the data obtained by Assistant J. H. Davis, 1881-'82.

Maximum gauge-reading, February 26	feet	102.801
Gauge-reading, February 22	do	101.301
Increment	do	1.5
Maximum width, February 28	do	2,694
Water area, February 22	square feet	196,020
Increment to water area (2,694 by 1.5)	do	4,041
Probable water area on February 26	do	200,061
Maximum mean velocity, March 1, per second	feet	8.246
Probable discharge on February 36 (200,061 by 8.3) per second	cubic feet	1,660,496

FULTON, TENNESSEE.

The discharge data obtained by Assistant W. H. Powless, 1879-'80, were used, as follows:

Maximum gauge-reading, March 1, 1882	feet	36.69
Low water of 1879, reads on gauge	do	2.14
High water 1882 above low water 1879	do	34.55
Stage March 24, 1880, above low water 1879	do	32.00
Stage March 1, 1882, above stage March 24, 1880	do	2.55
Maximum width of high water, 1880	do	2,615
Water area March 24, 1880	square feet	144,270
Increment (2,615 by 2.55)	do	7,668
Probable water area, March 1, 1882	do	151,938

$$V = 0.204\ (h-21.8),\ \text{Powless.}$$

Where $V=$ mean velocity, $h=$ gauge-reading above low water of 1879 $+27.77$ feet.
March 1, 1882, $V=0.204\ (62.32-21.8)=8.27$ feet per second.
Probable discharge on March 1, 1882 (151,938 by 8.27), 1,261,527 cubic feet per second.

HAMPTON.

This discharge-section was located about 12 miles below Memphis, and just below the junction of the bend and chute of President's Island.

The data used are those obtained from the observations of Prof. H. B. Herr, 1879.

High water of 1882, Memphis gauge	feet	35.15
Increment for oscillation at Hampton	do	1.72
Probable reading on Hampton gauge of high water of 1882	do	36.87
Stage on Hampton gauge, February 12, 1879	do	27.00
Increment	do	9.87
Width of river	do	4,600
Water area, February 12, 1879	square feet	179,948
Increment (4,600 by 9.87)	do	45,402
Probable water area for maximum stage, 1882		225,350

Using the formula deduced from Professor Herr's observations, by Assistant R. E. McMath:

$$V = .0725\ \Delta.$$

Where V = mean velocity, and Δ = stage on Hampton gauge + 37.18, we have, for high water of 1882:

$$V = .0725\ (36.87 + 37.18) = 5.37 \text{ feet per second.}$$

The probable discharge for high water of 1882 is (225,350 by 5.37) 1,210,130 cubic feet per second; hence, we get for flood of 1882:

COLUMBUS, KENTUCKY.

	Cubic feet per second.
Probable maximum discharge	1,660,000
Escape above	86,000
Total	1,746,000

FULTON, TENNESSEE.

Probable maximum discharge	1,261,000
Escape above	494,000
Total	1,755,000

HAMPTON.

Probable maximum discharge	1,210,000
Escape above	599,000
Total	1,809,000

These estimates give an increase of discharge of 9,000 cubic feet per second between Columbus and Fulton, and 63,000 cubic feet per second between Columbus and Hampton, which, considering the character of the work done on the Saint Francis Front, the number of small tributaries on the left bank of the river between these points, and the probable error in estimating the discharge of the river proper, may be regarded as a very close agreement.

TOTAL ESCAPE.

In order to form a conception of the volume of water that traverses the Saint Francis Bottom during the time of flood, the subjoined estimate has been made.

The right bank from Commerce, Mo., to opposite Memphis has been regarded as the river front that is tributary to the supply of the Saint Francis Bottom, for although there is a point some distance below Memphis which shows a greater net escape, this is due to the fact that a large quantity of water leaves the river there to return in a short distance, and it cannot properly be regarded as supply.

The amount of escape at mean flood stage was taken as the mean escape for the continuous flood period, that is, the number of consecutive days when the stage was above the flood zero.

Although there was no escape above New Madrid at mean flood stage, which was due, in all probability, to the deflection, by the ridge, of all of the overflow water and its return to the river, still, at an increased stage, such as the one when the examination was made, we find a net escape of 20,000 cubic feet per second, which was probably caused by a portion of the ridge being submerged and a consequent escape into the country back of it; and, as there were thirty-seven days during which the river was near, at, or above this stage, a mean discharge of 30,000 cubic feet per second has been assumed at this period of time.

	Cubic feet.
Above New Madrid, Mo., thirty-seven days, at 30,000 cubic feet per second	95,904,000,000
Between New Madrid and Fulton, seventy-eight days, at 154,000 cubic feet per second	1,037,837,000,000
Between Fulton and Memphis, eighty-eight days, at 67,000 cubic feet per second	509,414,000,000
Total escape	1,643,155,000,000

This amount of water is equal to 15.7 days' discharge of the river at Hampton, estimating its capacity as 1,210,000 cubic feet per second; or 10.5 days at 1,800,000 cubic feet per second.

Table of water escape of the flood of 1882 over that portion of the right bank of the Mississippi River forming the front of the Saint Francis Bottom, Commerce, Mo., to Helena, Ark.

[ABBREVIATIONS. V, surface velocity in feet per second. W, width in feet of the cross-section to which V and D are applied. S, soundings in feet. H, computed difference in feet between the stage of water at the time of observation and the stage for which the computation is made. D, computed depth. C, coefficients used to reduce V to mean velocity and to correct cross-section area for obstructions. A, direction of current, *f*, from river; *t*, toward; *n*, normal or at right angles with current of river; *d* diagonally, or a divergence of less than 45° with current of river, bearings are magnetic. Q, escape in cubic feet per second, with minus sign it indicates return flow. Q'', net escape in cubic feet per second.]

Locality.	Number.	Observation stage, March 7-15.								Maximum stage.				Mean flood stage.			
		V	W	S	C	A	Date of observation.	Q	Q''	H	D	Q	Q''	H	D	Q	Q''
							1882										
In apex of Lucas Bend	8*	0.875	9,050	5	.65	*f*, *n*	Mar. 13	25,730		3.02	8.02	41,177		1.20	3.80	19,559	
Opposite foot of Islands No. 3 and 4	9	1.250	11,900	2.5	.65	S. 70° W.	Mar. 10	24,172		2.98	5.48	52,598		1.18	1.32	12,763	
								40,908	49,908			93,775	93,775			32,322	32,322
Opposite Iron Bank	10	0.266	12,300	1.0	.65	S. 10° E.	Mar. 10	−2,127	47,781	2.70	3.7	−8,005	85,770	1.13			
Opposite Columbus, Ky	11	0.233	7,000	0.5	.65	*f*	Mar. 10	530		2.55	3.05	3,230		1.10			
Opposite head of Wolf Island, No. 5	12	0.4	17,000	4.5	.65	S. 20° W.	Mar. 10	19,890		2.6	7.1	31,382		1.12	3.36	14,940	
Opposite foot of Wolf Island No. 5	13	Slack		0.5			Mar. 10							1.16			
Head of Beckwith's Bend	14	1.920	5,800	2.5	.65	S. 50° W.	Mar. 10	16,596		2.77	5.27	34,863		1.18	1.32	8,731	
Center of Beckwith's Bend	15	1.406	9,300	7	.65	S. 60° W.	Mar. 10	62,034		2.80	9.80	86,867		1.19	5.81	51,487	
Foot of Beckwith's Bend	16	0.95	7,300	1	.65	*f*, *n*	Mar. 10	4,508		2.83	3.63	17,272		1.20			
								103,498	151,270			173,614	259,384			75,158	107,480
Foot of Island No. 6, below Hickman	17	Slack		2.5			Mar. 10										
Forty islands below Cairo	18	Slack.		3.5			Mar. 10										
Opposite French's Point	19	0.868	8,500	3.0	.65	*t*, *n*	Mar. 10	−14,534		3.08	6.08	−29,117		1.28	1.72	−8,330	
Opposite French's Point	20	0.606	8,400	5	.65	*t*, *n*	Mar. 10	−18,182		3.10	8.1	−29,484		1.29	3.71	−13,541	
Near Saint James Bayou	21	0.250	6,800	5	.65	*t*, *n*	Mar. 10	−5,525		3.15	8.15	−9,017		1.30	3.70	−4,069	
	21 a	0.383		15													
Saint James' Bayou	21 b	0.416	110	20	.8	*t*, *n*	Mar. 10	−471		3.15		−575		1.30		−428	
	21 c	0.335		8													
								−38,532	112,747			−68,193	191,191			−26,368	81,092

* From Commerce, Mo., to observation No. 8 there was no appreciable escape.

Table of water escape of the flood of 1882 over that portion of the right bank of the Mississippi River forming the front of the Saint Francis Bottom, Commerce, Mo., to Helena, Ark.—Continued.

Locality.	Number.	Observation stage, March 7-15.								Maximum stage.				Mean flood stage.			
		V	W	S	C	A	Date of observation.	Q	Q″	H	D	Q	Q″	H	D	Q	Q″
							1882.										
Bend of Island No. 8	22	Slack.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....
Center of Bend of Island No. 8	23	0.800	8,000	3	.65	S. 85 W.	Mar. 10	12,480	.....	3.21	6.21	25,844	.....	1.32	1.08	6,980	.....
Lower end bend of Island No. 8	24	0.733	8,000	4.5	.65	S. 85 W.	Mar. 10	17,162	.....	3.25	7.75	29,536	.....	1.33	3.17	12,083	.....
Just below, opposite foot of Island No. 8	25	0.500	7,700	0.5	.65	*f, n*	Mar. 10	1,251	.....	3.28	3.78	9,450	.....	1.35	.....	.....	.....
Upper side Donaldson's Point	26	0.733	.....	2.5	.....	*p, w*	Mar. 10	.....	.....	.....	.....	.....	.....	1.36	.....	.....	.....
Do	27	1.2	.....	2.5	.....	*p, w*	Mar. 10	.....	.....	.....	.....	.....	.....	1.37	.....	.....	.....
Do	28	1.2	7,000	2.0	.65	*n, f*	Mar. 10	10,920	.....	3.41	5.41	30,030	.....	1.38	0.02	3,320	.....
Do	29	0.9	3,700	3.	.65	*f, n*	Mar. 10	6,493	.....	3.44	6.44	13,949	.....	1.40	.....	.....	.....
Do	30	1.0	3,900	3.	.65	S. 85 W.	Mar. 10	7,665	.....	3.48	6.48	16,427	.....	1.40	1.60	4,050	.....
								55,901	108,648	.....	.....	125,245	316,436		.....	26,448	107,540
On Donaldson's Point	31	0.45	.....	3.5	.....	*p, w*	Mar. 10	.....	.....	.....	.....	.....	.....		.....	.....	.....
Down stream side Donaldson's Point	32	Slack.	.....	12	.....	.....	Mar. 10	.....	.....	.....	.....	.....	.....	1.46	.....	.....	.....
Do	33	Slack.	.....	6	.....	.....	Mar. 10	.....	.....	.....	.....	.....	.....	1.47	.....	.....	.....
Do	34	1.0	6,500	5	.65	*t, n*	Mar. 10	−21,125	.....	3.70	8.7	−36,757	.....	1.48	3.52	14,873	.....
Do	35	0.767	9,500	6	.65	*t, n*	Mar. 10	−28,417	.....	3.74	9.74	−46,121	.....	1.49	4.51	−21,380	.....
Upper end New Madrid Bend	36	0.833	8,000	9	.65	*t, n*	Mar. 10	−38,984	.....	3.78	12.78	−55,380	.....	1.50	7.50	−32,489	.....
Do	37	1.0	10,600	6	.65	*t, n*	Mar. 10	−41,340	.....	3.80	9.8	−67,522	.....	1.50	4.50	−31,005	.....
Saint John's Bayou	38 a 38 b 38 c	1.5 4.0 1.833	150	18 24 18	.80	*t, n*	Mar. 10	−6,240	.....	3.6	.....	−7,356	.....	1.48	.....	−5,806	.....
Little or Dry Bayou	39	1.5	1,000	12	.65	*t, n*	Mar. 10	−11,700	.....	3.6	15.8	−15,405	.....	1.47	10.58	−10,267	.....
								147,806	20,842			−228,541	87,895			−115,797	−8,257
Net escape above New Madrid	.....	.....	.....		.....	*t, n*	.....	.....	20,842	.....	.....	.....	87,895	.....	.....	.....	8,257
Just above upper end old Island No. 11.	40 41 42	0.5 0.5 0.95	200	2 1 1.5	.80	S. 50° W.	Mar. 10	166	.....	3.31	.....	509	.....	1.41	.....	.....	.....
On old Island No. 11	43	Slack	.....	6.5	.....	.....	Mar. 10	.....	.....	.....	.....	.....	.....	1.38	5.12	.....	.....
Upper side of Ruddle's Point	44 45 46	1.183 2.333 1.183	490	1 5 1	.80	N. 85° W.	Mar. 11	1,507	.....	3.18	.....	3,158	.....	1.28	.....	.....	.....
Lower side of Ruddle's Point	47 a 47 b	0.3 0.2	.....	3 4	.....	*f, n*	Mar. 11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Cushion Lake Bayou	47 e 47 47 d	1.2 1.33 1.2	50	9 13.5 9	.60	f, n	Mar. 11	527		2.82		663		1.18		462	
Do	47 e 47 f	0.8 0.207		4 5		f, n	Mar. 11										
Do	47 a, b 47 c, f	0.4	10,800	4 5	.65		Mar. 11	12,636		2.62	7.82	19,852		1.18	3.32	9,323	
Little Cypress Bend	48	0.722		3		p, w	Mar. 11			2.77	5.77			1.15	1.85		
Opposite lower end Island No. 13	49	0.8	23,650	1	.65	f, n	Mar. 11	12,298		2.57	3.57	43,964		1.07			
1½ miles below No. 49	50	1.333	1,300	1	.65	f, n	Mar. 11	1,126		2.48	3.48	3,921		1.05			
								28,250	49,092			72,007	159,902			9,785	9,785
Foot of Island No 14	51	1.333		2		p, w	Mar. 11			2.19				0.96			
Robinson Lake Bayou	52	0.667	120	5		t, n	Mar. 11	— 320		2.17	7.17	— 574		0.95	4.15	— 266	
Bank near Robinson Lake Bayou	52 a	0.500	2,400	3	.65	t, n	Mar. 11	— 2,340		2.17	5.17	— 4,033		0.95	2.15	— 1,677	
								— 2,660	46,432			— 4,607	155,295			— 1,943	7,842
One mile above Gayoso	53	0.467	12,300	3	.65	f, n	Mar. 11	11,200	57,632	2.10	5.1	19,042	174,837	0.93	2.17	8,300	16,142
Bayou at Gayoso	54	1.0	250	8	.8	t, n	Mar. 11	— 1,600	56,032	2.05	10.05	— 2,010	172,327	0.90	7.10	— 142	16,000
One mile below Gayoso	55	1.333	7,650	3	.65	f, n	Mar. 11	19,890		2.02	5.02	33,316		.89	2.11	13,973	
Two miles below Gayoso	56	1.2	5,850	4	.65	f, n	Mar. 11	16,252		1.98	5.98	27,288		.88	3.12	14,237	
1½ miles above Caruthville	57	1.467	8,200	1.5	.65	f, n	Mar. 11	11,729		1.94	3.44	26,916		.87	0.63	4,926	
Do	58	Slack		0.5			Mar. 11							.83			
One mile below Caruthersville	58 a 58 b 58 58 c 58 d	0.850 1.0 0.8 0.850 Slack.	600	2 2 3 1.5 0.5	.72	f, n	Mar. 11	790		1.8		1,409		.83	1.9	401	
								50,667	106,609								
1½ miles above foot Islands 16 and 17 in chute	59 a	1.5	1,500	1.0	72	f, n	Mar. 11	1,620		1.44	2.44	3,953		0.72	0.28	454	
One-fourth mile below foot Islands Nos. 16 and 17.	59	0.8		0.5		p, w	Mar. 11			1.4				0.70			
In chute of Island No. 16*	60																
Half Moon Bayou	60 a	0.5	150	2.0	.72	f, n	Mar. 11	108		1.26	3.26	176		0.68	1.82	71	
Break in levee	61	3.667	250	1.5	72	f, n	Mar. 11	1,044		1.24	2.74	1,908		0.68	0.82	571	
1 mile below Cottonwood Point	62	1.150	9,700	1.5	.65	f, n	Mar. 11	10,876		1.10	2.60	10,545		0.66	0.84	6,091	
Pemiscot Bayou	63 63 a 63 b	2.85	40	8 12 6	.8	N. 80° W.	Mar. 11	790		1.18		578		0.67	8.00	780	
Midway Landing opposite Island No. 21	64	1.333	10,900	2	.65	f, n	Mar. 11	18,889		1.17	3.17	29,970		0.67	1.83	12,610	
State line, Missouri and Arkansas	65	1.5	8,250	0.5	.65	f, n	Mar. 11	4,070		1.18	1.68	18,270		0.67			
Holman's Landing, opposite Island No. 21	66	1.0	10,560	5	.65	f, n	Mar. 11	34,320		1.12	6.12	42,008		0.66	4.32	28,652	

* Land about even with surface of water.

Table of water escape of the flood of 1882 *over that portion of the right bank of the Mississippi River forming the front of the Saint Francis Bottom, Commerce, Mo., to Helena, Ark.*—Continued.

Locality.	Number.	Observation stage, March 7-15.								Maximum stage.				Mean flood stage.			
		V	W	S	C	A	Date of observation.	Q	Q″	H	D	Q	Q″	H	D	Q	Q″
							1882.										
Hickman's Landing, opposite foot Island 21.	67	0.675	11,700	1	.65	f, n	Mar. 11	5,133		1.10	2.1	10,599		0.68	0.32	1,708	
Upper side of Wright's Point	68	1.0	6,950	1.5	.65	f, n	Mar. 11	6,777		1.09	2.59	11,701		0.70	0.80	3,614	
Lower side of Wright's Point	69	0.667	4,000	0.7	.65	f, n	Mar. 11	1,214		1.07	1.14	1,976		0.70			
Buckner's Landing, opposite Rucker's Point	70	Slack.		2			Mar. 11			1.02				0.72			
Barfield Landing	71	Slack.		4			Mar. 11			1.01				0.73			
1¼ mile below Barfield Landing	72	1.167	5,750	3	.65	f, n	Mar. 11	13,085		1.00	4.0	17,566		0.74	2.26	9,814	
Foot of Tow-head of Island No. 25	73	Slack.		3			Mar. 11							0.76			
Canadian Reach, opposite Forked Deer Island	74	1.250	9,400	5	.65	f, n	Mar. 11	38,187		0.92	5.92	45,214		0.77	4.23	32,242	
								136,113	242,812			287,453	459,780			131,184	147,184
Canadian Reach, opposite foot Forked Deer Island	75	0.733	8,500	1.5	.65	t, n	Mar. 11	— 6,075		0.91	2.41	— 9,779		0.78	0.72	—2,916	
Island No. 28, back Ashport bar	76	Slack.		2			Mar. 12							0.79			
Island No. 28, back Ashport bar	77	0.5	8,000	3	.65	t, n	Mar. 12	— 7,800		0.87	3.87	—10,088		0.80	2.20	—5,720	
Mill Bayou	78	0.467	150	15.5	.8	t, n	Mar. 12	— 869		0.84	16.34	— 916		0.80	14.70	— 824	
								—14,744	228,068			—20,783	438,997			—9,460	137,724
Fletcher's Landing, above Osceola	79	1.133	6,920	3.5	.65	f, n	Mar. 12	17,837		0.83	4.33	22,170		0.80	2.70	13,760	
Powless' (n. p.)	79 a	1.5	9,500	1.9	.65	f, n	Mar. 12	17,599		0.81	2.71	25,132		0.81	1.09	10,096	
								35,436	263,504								
Elmot Landing	80	Slack.		1.5						0.8				0.82			
Net-escape above Osceola, Ark.									263,504			47,302	486,299			23,856	161,580
Opposite angle of Bullerton Tow-head	81	3.0	600	4.5	.65	f, n	Mar. 12	5,265		0.77	5.27	6,166		0.84	3.66	4,282	
Tanza Landing	82	2.667	250	2	.65	f, n	Mar. 12	867		0.75	2.75	1,191		0.85	1.15	498	

Craighead Point, upper side ..	83	1.533	9,200	2.5	.65	f, n	Mar. 12	23,107	....	0.72	3.22	35,605	....	0.86	1.64	15,198	....
								29,200	292,803	......	......	42,962	529,261	....	....	19,976	161,658
Craighead Point, lower side ...	84	1.133	6,700	0.5	65	t, n	Mar. 12	—32,072	260,731	0.70	7.20	—35,537	493,724	0.89	5.61	—27,681	153,877
Net escape above Old Fulton discharge section.		......	......	......	......	....	......	......	260,731	......	......	....	493,724	......	......	....	153,877
In Chute Island 34, opposite upper end of island.	85	1.0	130	1.5	.65	f, n	Mar. 12	920	....	0.64	2.14	741	....	0.91	0.59	622	
	86	1.667	60	2.0	.65	f, n				0.64	2.64			0.91	1.09		
	87	2.15	85	2.5	.65	f, n				0.64	3.14			0.91	1.59		
In chute opposite middle Island 34.	88	2.0	90	3.0	.65	f, n	Mar. 12	....	....	0.64	3.64	426	....	0.92	2.08	....	....
Nodena or Fletcher's Landing, in chute of Island No. 34.	89	3.133	1,200	0.7	.65	f, n	Mar. 12	1,710	....	0.63	1.33	3,253	....	0.93	......	....	....
Upper side Morgan's Point	90	2.0	.....	5.0	......	p, w	Mar. 13	....	....	0.62	......	....	....	0.94	4.06	....	....
Lower side of Morgan's Point, opposite head Island 35	91	Slack.	.....	0.8	.....	....	Mar. 13	....	....	......	......	....	....	0.96	......	....	....
Lanier's bend of Island 35	92	2.15	500	3.0	.65	f, n	Mar. 13	2,096	....	0.60	3.6	2,515	....	1.01	1.99	1,540	....
One half mile below Lanier's	93	0.8	1,800	1.0	.65	f, n	Mar. 13	936	....	0.60	1.6	2,148	....	1.01	......	....	....
One and three-quarter miles below Lanier's	94	1.467	150	2.5	.72	f, n	Mar. 13	396	....	0.60	3.1	491	....	1.02	1.48	234	....
Bend of 35, mile above Pecan Point.	95	Slack.	.....	0.8	.....	....	Mar. 13	....	....	......	......	....	....	1.04	......	....	....
Bayou at Pecan Point	96	0.5	40	2.5	.8	f, n	Mar. 13	40	....	0.58	3.08	50	....	1.04	1.46	28	....
								6,096	268,829			9,624	503,348			2,419	150,296
Shawnee Landing, bend of Island 37	97	0.750	750	2.5	.8	t, n	Mar. 13	—1,125	265,704	0.55	3.05	—1,380	501,968	1.10	1.40	—630	155,666
One half mile above Viola Landing, in Devil's Elbow Bend	98	1.8	90	1.5	.72	f, n	Mar. 13	175	....	0.54	2.04	246	....	1.12	1.38	161	....
Old chute, Island 38, in Devil's Elbow Bend	99	0.867	150	2.5	.8	f, n	Mar. 13	260	....	0.54	3.04	317	....	1.13	1.37	143	....
Lower chute, Island 38, Devil's Elbow Bend	100	1.133	275	3.0	.8	f, n	Mar. 13	748	....	0.53	3.53	880	....	1.13	1.87	466	....
Fogleman's Chute	101	0.933	10,000	1.0	.65	S. 30 W.	Mar. 13	6,065	....	0.53	1.53	9,295	....	1.14	......	....	....
								7,248	272,952			10,738	512,706			770	156,436
Poker Point	102	Slack.	.....	4.5	.....	....	Mar. 13	....	....	......	......	....	....	1.10	......	....	....
Opposite Beef Island Chute, upper end	103	0.5	.....	2.5	.....	p, w	Mar. 13	....	....	......	......	....	....	1.17	......	....	....
Upper end of Beef Island Bend	104	0.4	10,400	5.0	.65	t, n	Mar. 13	—13,520	259,432	0.51	5.51	—13,572	....	1.17	3.83	—10,356	....
Bayou at Bradley's Landing. ..	105	1.0	60	1.5	.8	t, n	Mar. 13	— 60	....	0.50	1.5	— 610	....	1.18	0.32	— 13	....
Break in levee	105 a	0.75	150	2.5	.72	t, n	Mar. 13	— 202	....	0.50	3.0	— 243	....	1.18	1.32	— 107	....
								— 262	259,170			—14,425	498,281			—10,476	145,960
Beef Island Bend, opposite Island No. 40	106	0.533	7,000	4.0	.65	f, n	Mar. 13	9,700	....	0.50	4.5	10,920	....	1.19	2.81	6,815	....
Do	107	1.4	7,800	6.0	.65	S. 70 W.	Mar. 13	4,259	....	0.50	0.5	46,137	....	1.20	4.80	34,070	....
Do	108	0.2	7,200	3.0	.65	f, n	Mar. 13	2,808	....	0.50	3.5	3,276	....	1.21	1.79	1,675	....

Table of water escape of the flood of 1882 *over that portion of the right bank of the Mississippi River forming the front of the Saint Francis Bottom, Commerce, Mo., to Helena, Ark.*—Continued.

Locality.	Number.	Observation stage, March 7-15.								Maximum stage.				Mean flood stage.			
		V	W	S	C	A	Date of observation.	Q	Q''	H	D	Q	Q''	H	D		Q''
							1882.										
Beef Island Bend, opposite Island No. 40	109	1.333	4,400	3.5	.65	*f, n*	Mar. 13	13,347		0.49	3.49	15,168		1.22	2.28	8,694	
Beef Island Bend, opposite Island No. 41.	110	1.6	4,200	5.0	.65	*f, n*	Mar. 13	21,840		0.49	5.49	24,024		1.22	3.78	16,511	
Redman's Point, upper side	111	1.133	5,800	1.0	.65	*f, n*	Mar. 13	4,271		0.48	1.48	6,490		1.23			
								56,225	315,395			106,024	604,305			67,765	213,725
Redman's Point, lower side	112	0.6		3.0		*p, w*	Mar. 13							1.24	1.76		
Two bayous behind Chicken Island.	113	4.0	250	7.0	.8	*t, n*	Mar. 13	— 5,600		0.47	7.47	— 5,980	508,325	1.27	5.73	— 4,584	
Right bank of chute of Chicken Island.	113 a	0.267	14,000	2.5	.65	*t, n*	Mar. 13	— 6,074		0.47	2.97	— 7,280	591,045	1.27	1.23	— 2,999	
								—11,674	303,721							— 7,583	206,142
Chute of Chicken Island	114	1.333		32.0		*p, w*	Mar. 13							1.27			
Below mouth of chute	115	1.6	3,000	6.0	.65	*f, d*	Mar. 13	18,720		0.46	6.46	20,280	611,325	1.28	4.72	14,726	220,868
Hopefield Point	116	0.7		1.5		*p, w*	Mar. 14							1.30	0.20		
Net escape above Hopefield*									322,441				611,325				220,868
Lower side of Hopefield Point	117	2.4	4,000	1.0	.65	*t, n*	Mar. 14	— 6,240		0.61	1.61	—10,040					
	118	3.2	300	1.0	.65	*t, n*	Mar. 14	— 624		0.62	1.62	— 1,010					
Falls—Difference in height, 1½ feet	119	2.4	50	1.5		*t, n*	Mar. 14	— 1,000		0.62		— 270					
Falls—Difference in height, 2 feet	120	5.5	250	1.0		*t, n*	Mar. 14	— 1,400		0.63	1.63	— 2,100					
Do	120 a	1.5	6,000	1.0	.65	*t, n*	Mar. 14	— 5,850		0.63	1.63	— 9,516					
								—15,114	307,327			—22,936	588,389				
President's Island bend	121	1.7	2,500	2.0	.65	*f, n*	Mar. 14	5,525		0.64	2.64	7,292					
Do	122	1.533	400	2.5	.65	*f, n*	Mar. 14	996		0.65	3.15	1,256					
Do	123	1.533	1,000	1.5	.65	*f, n*	Mar. 14	1,495		0.66	2.16	2,151					
								8,016				10,699	599,088				
Net escape above Hampton cross-section									315,343				502,088				
Horn Lake bend	124	0.667	3,000	8.0	.65	*f, n*	Mar. 14	3,902	319,245	0.67	3.67	4,797	603,885				

[illegible]	[illegible]	1.8	300	3.0	.72	[illegible]	[illegible]										
	126	1.338	5,000	2.0	.65	f, n	Mar. 14	8,667	....	0.70	2.70	11,700	....				
Graves' Bayou	127	0.20	50	6.0	.80	f, n	Mar. 14	48	....	0.71	6.71	54	....				
								8,715	320,794								
	128	0.40	2,600	1.0	.65	t, n	Mar. 14	—676	....	0.72	1.72	1,166	....				
												12,920	615,371				
Break in levee	129	1.75	320	5.5	.65	t, n	Mar. 14	— 2,002	....	0.75	6.25	— 2,275	....				
Break in levee	130	0.45	300	1.8	.8	t, n	Mar. 14	— 194	....	0.76	2.56	— 278	....				
Vicinity of Porter Bayou	131	1.533	3,000	9.0	.65	t, n	Mar. 14	—26,904	....	0.77	9.77	—29,211	....				
Porter or Lost Bayou	132 a	0.4	250	3.0	.8	t, n	Mar. 14	—2,397	....	0.78	......	— 2,049	....				
	132 c	1.5		22.5		t, n	Mar. 14										
	132 b	0.5		2.0		t, n	Mar. 14										
								—32,173	294,621			—33,813	581,558				
Upper portion Buck Island bend 2½ miles below Bennet's Landing	133	0.567	4,000	1.0	.65	f, n	Mar. 14	1,474	....	0.78	1.78	2,314	583,872				
	134	0.533	3,000	1.5	.65	f, n	Mar. 14	1,559	....	0.79	2.29	2,379	....				
	135	1.067	3,000	3.0	.65	f, n	Mar. 14	6,242	....	0.80	3.80	7,897	....				
								9,275	303,896			10,276	594,148				
	136	1.700	11,000	6.0	.65	t, n	Mar. 14	—72,930	....	0.80	6.80	—82,654	....				
Holtbee Bayou	137	1.600	100	10.5	.8	t, n	Mar. 14	— 1,344	....	0.81	11.31	— 2,317	....				
Council Bend	137 a	1.600	7,000	3.0	.65	t, n	Mar. 14	—21,840	....	0.81	3.81	—27,755	....				
Frenchman's Bayou	138	0.200	200	18.0	.8	t, n	Mar. 14	—576	....	0.81	18.81	—602	....				
								—96,690	207,206			—113,328	480,820				
Council Bend	139	1.333	4,000	6.5	.65	f, n	Mar. 14	22,530	....	0.81	7.31	25,350	....				
Do	140	0.533	......	5.0	......	p, w	Mar. 14						....				
Council Bend	141	2.6	3,000	6.0	.65	f, n	Mar. 14	30,420	....	0.82	6.82	34,554	....				
Mouth of Council Bend	142	0.767	......	3.0	......	p, w	Mar. 15						....				
Upper portions of Ashley Point	143	1.150	5,000	7.0	.65	f, n	Mar. 15	26,162	....	0.82	7.82	29,250	....				
Do	144	Slack	......	6.5	......	....	Mar. 15						....				
Do	145	0.700	3,000	6.0	.65	f, n	Mar. 15	8,190	....	0.83	6.83	9,321	....				
								87,302	294,508	......	......	98,475	579,295				
Lower portions of Ashley Point	146	1.133	3,000	6.0	.65	t, n	Mar. 15	—26,512	....	0.86	6.86	—30,303	....				
Walnut Bend	147	1.333	6,000	3.0	.65	t, n	Mar. 15	—15,600	....	0.86	3.86	—20,085	....				
Do	148	1.333	8,000	7.0	.65	t, n	Mar. 15	—48,553	....	0.86	7.86	—54,496	....				
Do	149	1.267	100	8.0	.8	t, n	Mar. 15	— 811	....	0.86	8.86	— 898	....				
Do	150	0.533	6,000	6.0	.65	t, d	Mar. 15	—12,472	....	0.86	6.86	—14,274	....				
Do	151	1.133	6,000	2.5	.65	t, n	Mar. 15	—11,047	....	0.86	3.36	—14,820	....				

* Hopefield, Arkansas, being considered as the limit of supply to the Saint Francis Bottom, the computation for mean flood stage was made to that point only.

Table of water escape of the flood of 1882 *over that portion of the right bank of the Mississippi River forming the front of the Saint Francis Bottom, Commerce, Mo., to Helena, Ark.*—Continued.

Locality.	Number.	Observation stage, March 7-15								Maximum stage.				Mean flood stage			
		V	W	S	C	A	Date of observation	Q	Q′	H	D	Q	Q″	H	D	Q	Q″
							1882.										
Walnut Bend	152	1 150	5,000	8 0	.65	t, d	Mar 15	— 11,212	......	0.87	3.87	— 14,462	...	...	...	...	...
								—126,207	168,301			—149,338	429,957	...	...	...	...
Upper side Hardin's Point	153	0 325	14,000	6 0	.65	f, n	Mar. 15	17,745	......	0 87	0 87	20,584	...	...	...	...	...
Do	154	1 733	10,000	6.5	.65	f, n	Mar. 15	73,319	...	0.87	7 37	83,005	...	...	...	...	...
								90,064	259,265			103,589	533,546	...	...	...	...
Lower side Hardin's Point	155	1 000	24,000	7 0	.65	t, n	Mar 15	—109,200	......	0.88	7 88	—122,928	...	...	...	...	...
	167 a	1 867	100	10 0	.8	t, n	Mar 15	— 1,494	...	0.88	10 88	— 1,625	...	...	...	...	...
Upper chute of Saint Francis Island	167	1.633	50	10.5	.8	t, n	Mar 15	— 644	....	0.88	11 38	— 698	...	...	...	...	...
Lower chute of Saint Francis Island	166	2 000	100	24.0	.8	t, n	Mar. 15	— 3,840	......	0 89	24 89	— 3,982	...	...	...	...	...
Between lower end of Saint Francis Island and mouth of Saint Francis River	165 a	1 067	24,000	7 0	.65	t, n	Mar 15	—116,516	...	0 89	7 89	—131,502	...	...	...	...	...
1½ miles above mouth of Saint Francis River	165	1 133	50	10 5	.8	t, n	Mar 15	— 476	...	0 89	11 39	— 516	...	...	...	...	...
Left bank mouth of Saint Francis River	164	1 430	2,000	6.0	.65	t, d	Mar. 15	— 11,164	...	0.89	6 89	— 12,676	...	...	...	...	...
The whole distance from mouth of Saint Francis River to Helena was multiplied into the arithmetical mean of V, multiplied by S, or mean velocity (in square feet) per linear foot of river front.	163	1 000		4 0						0.89	4 89						
	163 b	1 200		5.0						0.89	5 89						
	163 c	1 333		4 5						0.89	5.39						
	162	1.500		6.0						0 89	6 89						
	161	1 600		6.5						0 89	7 39						
	160	2.000	36,000	6.0	.65	t	Mar 15	—169,884	....	0 89	6 89	—196,934	...	...	...	...	...
	159	1 900		5.0						0 89	5.89						
	158	0.200		4 5						0.89	5 39						
	157	1 100		7.5						0 90	8.40						
	156	0.900		8 0						0 90	8 90						
								—413,208	—153,943			—470,860	62,686	...	...	...	...
Excess of outflow over inflow along the Saint Francis front	...	...	...	...	...	...	...	...	153,943	...	...	...	162,686	...	...	...	...

3.—White River and Tensas Fronts, and Arizona and Landry Crevasses, Flood of 1882.

(Observations by J. B. Johnson and Hunter Stewart, United States Assistant Engineers.)

(Report by Hunter Stewart, United States Assistant Engineer.)

Office of Mississippi River Commission,
Saint Louis, Mo., April 17, 1883.

Sir: I have the honor to submit, herewith inclosed, a report upon the reconnaissance, during the flood of 1882, of that portion of the right bank of the Mississippi River situated between Helena, Ark., and the mouth of Cypress Creek; upon the high water examination of the Tensas Front, for the flood of 1882, and upon the examination of the right bank from Red River to Donaldsonville during the same flood.

Very respectfully, your obedient servant,

Hunter Stewart,
United States Assistant Engineer.

First Lieut. Smith S. Leach,
Secretary Mississippi River Commission.

REPORT.

WHITE RIVER BOTTOM.

The steam-tug Frolic was detailed for this service.

The engineer force consisted of J. B. Johnson and Hunter Stewart, United States assistant engineers.

The methods of making observations and of estimating the discharge were similar to those used by Messrs. Johnson and Stewart in their examinations of the Yazoo and Saint Francis fronts, respectively, for the flood of 1882, and are described in their reports respecting the same.

The bottoms situated back, or west, of the section of the Mississippi River under consideration may be divided into three sections or basins:

(1.) The White River bottoms, or that portion of the overflowed lands situated between Helena and the mouth of the White River.

(2.) The islands surrounded by the White, the Arkansas, and the Mississippi rivers.

(3.) The Arkansas River and Cypress Creek bottoms, which extend from the mouth of the Arkansas River to Cypress Creek.

These three basins, taken either separately or conjointly, have comparatively but small capacity to deplete the Mississippi River of its flood waters, or to perform the function of reservoirs to the same.

In view of the above fact in connection with the subsidence of the flood and the more important work which had to be done below, the examinations of these fronts were made in a cursory manner, and only the more important features were noticed.

Such observations as were made are given below. On March 25, 1882, the crevasse just below Helena was examined:

Width (estimated), 2,500 feet.
Surface velocity, 3.4 feet per second.
Depth (mean of soundings), 9 feet.
Coefficient to reduce surface velocity to mean velocity, .7.
Discharge, 54,000 cubic feet per second.

For maximum stage:	Feet.
Helena gauge, March 8, 1882, maximum	47.2
Helena gauge, March 25	45.2
Increment	2.0

Discharge, 63,000 cubic feet per second.

This result may be regarded as approximately correct, as the increase in the cross-section area, due to the probable widening of the crevasse, may be considered to be compensated in the discharge computation by the reduction in surface velocity due to the filling up of the swamps and the reduction of head by the fall of the river itself.

March 27, at Westover, opposite Friar's Point, there were three breaks:

Width (aggregate), 1,200 feet.
Surface velocity (mean), two-thirds foot per second.

Depth (mean of soundings), 4½ feet.
Discharge, 2,500 cubic feet per second.

On Kangaroo Point the water was flowing back into the river for a distance of 2,600 feet and at the rate of 1 cubic foot per second per linear foot. Return flow, 2,600 cubic feet per second.

From Kangaroo Point to Old Town Landing there were two breaks in the levee, 300 and 110 feet wide, respectively, at the date of observation. When examined the currents in these were from the river at the rate of one-third of a foot per second on the surface. From information received, it was learned that at the highest stage of the river these were discharging into the river with considerable velocity. This feature was probably due to the influence of the Old Town Ridge. From Old Town Landing to Cockleburr Bayou six breaks in the levee were reported.

LACONIA CIRCLE.

This tract of land, situated just above the mouth of White River, is subject to submergence from three sources, *i. e.*, the Mississippi River on its own front, the overflow water from the Mississippi River that escapes above, and the White River in the rear; it is completely surrounded with levees, which are intended to protect it from these. During the flood of 1882 but little damage was done previous to the rise in the White River, which backed up the overflow water that escaped from the Mississippi River above until it rose higher than the back levees and, breaking these, inundated the circle. When the circle was filled, the overflow above continuing and being deprived of its usual outlet through the White River, the water rose above the front, or Mississippi River levees, and running over, broke them.

The water on the inside of the circle was from 1 to 1¼ feet higher than the Mississippi River in the vicinity of Graddy's Landing, Desha County, Arkansas.

DISCHARGE OF THE WHITE RIVER.

On March 27 Montgomery Pass or Cut-off was examined. No perceptible current was found. The mean depth was 29 feet.

On March 28 the White River proper was gauged. The discharge section was located one-half mile below the head of Montgomery Pass, the base line and the width of the river were measured by means of the stadia, the ranges and base were located with a prismatic compass, seven soundings were taken approximately equidistant, and four rod floats were run, also approximately equidistant.

The base was 121 feet long, and the floats consisted of a 2-inch rod weighted to an immersion of 16 feet. The coefficient of nine-tenths is used to reduce the measured velocity to mean velocity, as the floats were run at an immersion a little less than one-third of the mean depth.

Width of the river, 750 feet.
Mean depth, 42.5 feet.
Mean of measured velocities, 4 feet per second.
Discharge, 115,000 cubic feet per second.

There was no apparent movement in the overflow on the right bank of the White River from the locality of the discharge section to the mouth, while there was an inflow into the White River over the left bank of about 1 cubic foot per second per linear foot. This would give the discharge of the White River into the Mississippi at the date of observing, 117,500 cubic feet per second.

Discharge of the White River at the maximum stage.

Water gauge at the mouth of White River:

	Feet.
Maximum stage, February 28, 1882	48.4
Observation stage, March 28, 1882	46.2
Increment	2.2

Mean depth for maximum stage, $42.5 + 2.2 = 44.7$ feet.
Discharge, 121,000 cubic feet per second.

Supposing that at the maximum stage the discharge over the bank into the White River was double what it was at the observed stage, we would get 126,000 cubic feet per second as the total discharge of the White into the Mississippi at maximum stage.

Between the mouths of the White and Arkansas rivers.

From the mouth of the White River down the Middle Ground to the mouth of the Arkansas River, there was no apparent current, the land varying from 1 foot submergence to 1 foot exposure.

DISCHARGE OF THE ARKANSAS RIVER AT ITS MOUTH.

The observations were made on March 28, 1882. The discharge section was located 300 yards above the mouth of the Arkansas, and the methods used were the same as those employed in determining the discharge of the White River.

Width of Arkansas River, 750 feet.

Depth (mean of 8 soundings), 40.7 feet.

Mean of observed velocities, 2.17 feet per second.

Coefficient of reduction, .9.

Approximate discharge for observed stage, 62,000 cubic feet per second.

For maximum stage.

	Feet.
Maximum stage, Arkansas City gauge	47.1
Stage on March 28, Arkansas City gauge	44.1
Difference of stage	3.0
Mouth of White River, difference of stage	2.2
Increment for Arkansas River	2.7

Assuming that the other conditions are equal, we have for maximum stage:

Mean depth 40.7+2.7=43.4 feet, and discharge 64,000 cubic feet per second.

BAYOU ONE MILE ABOVE CYPRESS CREEK.

Width (effective), 130 feet.

Velocity, surface, 3.5 feet per second.

Mean depth, 33.4 feet.

Coefficient of reduction, .8.

Discharge, 12,000 cubic feet per second.

For maximum stage.

Mean depth, 33.4+2.6=36 feet.

Discharge, 13,000 cubic feet per second.

From the above bayou to Cypress Creek there was a flow into the Mississippi River of 9,000 cubic feet per second.

CYPRESS CREEK.

Cypress Creek was discharging into the Mississippi River, and the following estimate of the amount is made from the observations:

The total distance sounded was 1,000 feet, which is divided into two sections, *i. e.*, the main channel, Cypress Creek proper, and the auxiliary channel, or the sum of the distances on each side for which the velocity of the current was greater than that usual in the overflow.

For the main channel.

Width (estimated), 170 feet.

Mean depth, 30¼ feet.

Surface velocity, 2.1 feet per second.

Coefficient of reduction, .8.

Discharge, 8,700 cubic feet per second.

For the auxiliary channel.

Width, 830 feet.

Mean depth, 10 feet.

Surface velocity, 1½ feet per second.

Coefficient of reduction, .65.

Discharge, 6,800 cubic feet per second.

Total discharge of Cypress Creek at the date of observing, 15,500 cubic feet per second.

There is given below a tabulation of the discharge of such outlets as were gauged; also an estimate of their discharge at the maximum stage of the river.

These observations were scattering, and can give no conception of the total amount of water-escape from, or of the action of the overflow upon, that portion of the river bank which is comprised between their limits; nor is this report made with any such view, as there was no attempt at either a thorough examination or even a rough estimate of the movement of the overflow, for reasons hereinbefore mentioned.

The principal tributaries of the Mississippi River were, however, roughly gauged, as it was thought that such data would be of interest and, perhaps, of service in other relations, as well as that of high-water escape.

Table of measured discharges between Helena and the mouth of Cypress Creek:

Locality.	Stage at the time of observation.		Estimate for maximum stage.	
	Escape from river per second.	Flow into river per second.	Escape from river per second,	Flow into river per second.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Helena	54,000		63,000	
Westover	2,500		10,000	
Kangaroo Point		2,600		12,000
Old Town Landing	600			18,000
White River		117,500		126,000
Arkansas River		62,000		64,000
Bayou, 1 mile above Cypress Creek		12,000		13,000
Between above bayou and Cypress Creek		9,000		9,000
Cypress Creek		15,500		18,300
Totals	57,100	218,600	73,000	260,300

TENSAS FRONT.

This section of the front of the Mississippi River extends along the right bank of the same, from Cypress Creek to the mouth of Red River.

The examination was made as follows:

March 29, 1882, a set of observations was made between Arkansas City and the west bank of Bayou Maçon, along the line of the Little Rock, Mississippi River and Texas Railroad, in order to determine the amount of water flowing through the bottoms.

This was done to obviate the necessity of measuring the inflow and outflow along the banks of the streams contiguous to this section, viz, the west bank of the Cypress Creek, from where it leaves the high land, to its mouth, and the west bank of the Mississippi River, from the mouth of Cypress Creek, to Arkansas City.

After the completion of the above, the right bank of the Mississippi River was examined from Arkansas City to Point Chicot.

March 30, 1882, the right bank was followed from Leland's to Ashton, after which the Frolic proceeded to Vicksburg to await orders. On the way down, Mr. J. B. Johnson, United States assistant engineer, made a second estimate of the breaks between Alsatia and Delta, La.; the first one having been made by him on March 21, 1882, after his reconnaissance of the Yazoo Front. Both estimates are given in the tabulated results.

March 30, 1882, orders were telegraphed for and their arrival awaited.

March 31, 1882, that portion of the Tensas Front comprised between Delta, La., and Shipp's Bayou, was examined.

April 2, 1882, the examination was continued from Shipp's Bayou to Waterproof.

April 3, 1882, the right bank was followed from Waterproof to the mouth of Red River, and the examination of the Tensas completed.

MODE OF OBSERVING.

As there was considerable escape into the swamps over the right bank of Cypress Creek, from where it leaves the high land to its mouth, and as there were frequent variations in the direction of the movement of the overflow water on that portion of the right bank of the Mississippi River extending from the mouth of Cypress Creek to Arkansas City, it was deemed more expedient to estimate the net escape above this latter point, by measuring the amount of water flowing through the bottoms on this latitude and making due allowance for the contribution of local watersheds, than to follow the entire tributary front; especially as the observations made under the latter method would have been more imperfect in their character.

Discharge observations over the line of the railroad from Arkansas City to Bayou Maçon were made as follows:

The widths of the sections were measured with a tape line along the bridges, trestles, and culverts, soundings were taken every 50 feet, and the surface velocity was measured with a log and line at intervals of 100 feet or less, as the variation in velocity demanded.

In computing the results, a coefficient of .8 is used to reduce the velocity at the surface to a mean.

From Arkansas City to Ashton and from Delta to the mouth of Red River the following methods were used:

Where there were breaks in the levee of requisite importance the width was measured with the stadia, the section in the line of the levee was sounded, and the surface velocity was measured with the log and line. If the section comprised between the ends of the levee showed a large amount of scour, attributable to the vertical movement of the water flowing through it, an auxiliary section was sounded, either in front, if the batture was extensive, or in the rear of the levee, where the vertical equilibrium of the water was somewhat restored; a velocity was measured for this auxiliary section and the width of the same estimated. Where the water was flowing over the top of the levee for a long stretch, the amount of discharge per linear foot was estimated and afterwards multiplied by the total distance found subject to such submergence. For small breaks the output was either disregarded or the discharge estimated in its entirety.

REDUCTION.

The following formula is used for computing the discharge:

$$Q = V \times W \times D \times C,$$

wherein:

Q = discharge.
V = surface velocity.
D = depth or mean of soundings.
W = width of cross-section.
C = coefficient of reduction.

COEFFICIENT.

The only velocity measured being that of the surface, a reduction to mean velocity is necessary in order to obtain the true discharge. The following have been adopted:

For open streams, mean velocity = surface velocity × .8.
Eor crevasses, mean velocity = surface velocity × .7.
For discharge over the banks, mean velocity = surface velocity × .65.

STAGE.

At Arkansas City the maximum gauge height occurred on February 28, nine days before the main flood-wave had reached Helena, while at Greenville it occurred on February 27, ten days previous.

At Lake Providence and Vicksburg the highest stage was reached on March 20, eleven days after the crest of the flood-wave reached Helena.

GAUGE-READINGS AND DIFFERENCES OF STAGE AT THE GAUGE STATIONS.

	Feet.
Arkansas City:	
Highest stage, February 28, 1882	47.10
Observed stage, March 29, 1882	44.05
Difference	3.05
Greenville:	
Highest stage, February 27, 1882	41.70
Observed stage, March 30, 1882	40.65
Difference	1.05
Lake Providence:	
Highest stage, March 20, 1882	38.32
Stage of first observation, March 20, 1882	38.32
Stage of second observation, March 30, 1882	36.35
Difference	1.97
Vicksburg:	
Highest stage, March 20 and 21, 1882	48.75
Observed stage, April 1, 1882	47.00
Difference	1.75

	Feet.
Saint Joseph, La.:	
Highest stage, March 20, 1882	44.90
Observed stage, April 2, 1882	43.85
Difference	1.05
Natchez:	
Highest stage, March 28 and 29, 1882	47.75
Observed stage, April 3, 1882	47.20
Difference	0.55
Red River Landing:	
Highest stage, March 27, 1882	48.50
Observed stage, April 3, 1882	48.10
Difference	0.40

Estimate of the amount of water flowing through the bottoms between Arkansas City and the west bank af Bayou Maçon, from measurements made along the line of the Little Rock, Mississippi River and Texas Railroad, on March 29, 1882.

Locality.	Cross-section area.	Mean velocity per second.	Discharge per second.
	Sq. ft.	*Feet.*	*Cu. ft.*
Chicot Bayou	16,748	1.35	22,600
Boggy Bayou	19,475	1.32	25,700
Culverts	375	2.16	800
Fulton Bayou	10,520	1.60	16,900
Dead Man's Bayou	13,375	1.28	17,200
Maçon Bayou	6,061	1.76	10,700
Total	66,554	1.41	93,900
Less, for local water-sheds			30,000
Amount of escape on this line			63,900

The maximum stage in the overflow was 32 inches above the observed stage.

For maximum stage:

	Cubic feet per second.
Escape at observed stage	63,900
Increment, 5,840 × 2.7 × 1.4	22,100
Escape at maximum stage	86,000

These figures give the probable net escape from Cypress Creek and the Mississippi River into the Tensas Bottoms above Arkansas City, for the maximum stage and a stage 3 feet below the maximum.

WATER ESCAPE INTO THE TENSAS BOTTOMS AT THE TIME OF OBSERVING.

	Cubic feet per second.
Net escape above Ashton	118,000
Net escape from Ashton to Delta	219,000
Net escape from Delta to the mouth of Red River	49,000
Total	386,000

Maximum stage.

There are many important features of the flood regimen of the Mississippi River which bear upon the question of what constitutes a maximum stage for the entire Tensas Front, of which the following are some:

The division of the main flood-wave on the Yazoo Front into two parts, one passing down the river channel and the other through the Yazoo Bottoms; and the near proximity to the upper portion of the Tensas Front of two affluents of the size and importance of the White and Arkansas rivers.

The point of juncture of the flood-wave from these tributaries with the wave descending from Cairo, and its relation to the precedence, coincidence, or sequence of the crests, often give a maximum stage along the upper portion of the front, which is considerably anterior to that of the lower, while the more or less perfect conjunction, at the mouth of the Yazoo River, of the two portions of the original flood-wave, has its effect upon the stage of the river for a considerable distance above, as well as along the whole section of the Tensas Front lying below.

The following data, bearing upon the relation of stage and discharge of the Mississippi River at flood-stage, are taken from the results of the observations made by Assistant Engineer Homer P. Ritter:

Discharge observations at Hays' Landing, Miss.

(Homer P. Ritter, U. S. assistant engineer in charge.)

	January 21, 1882.	March 20, 1882, maximum stage.	March 29, 1882.	June 1, 1882, maximum discharge.
Gauge-reading .... feet..	34.28	38.58	36.06	34.14
Water area.... square feet..	161,534	172,105	164,614	167,396
Width .... feet..	2,710	2,820	2,756	2,707
Mean velocity... ft. per sec..	6.06	5.44	5.56	6.26
Discharge... cu. ft. per sec..	978,300	936,900	914,800	1,049,000

These figures show that the reunion, at the mouth of the Yazoo River, of the two parts of the original flood-wave resulted in an increase of stage above, for a given discharge, or, viewed in relation to the maximum discharge, in rendering negative the increment of discharge for proportionate gauge heights, and in a retardation of the passage of the flood-wave.

As the maximum discharge did not occur at the maximum stage, the amount of escape from the river at said stage cannot be regarded as indicating the increment in gauge height which would occur if the escape were confined to the river under normal conditions; that is, where the propagation of the flood-wave is restricted to the river channel.

The following estimate of net escape is made for maximum stage:

	Cubic feet per second.
From the mouth of Cypress Creek to Ashton	150,000
From Ashton to Delta, La..	300,000
From Delta, La., to the mouth of Red River............................	50,000
From maximum stage along the Tensas Front............................	500,000

TENSAS FRONT, FLOOD OF 1882.

Mouth of Cypress Creek to Louisiana State line.

[Observation by Hunter Stewart and J. B. Johnson.]

Locality.	Velocity.	Width.	Depth.	Coefficient.	Date of observation.	Outflow.
Estimate of overflow water from Cypress Creek and Mississippi River, flowing through the bottoms along the line of the Little Rock, Mississippi River and Tensas Railroad.......	....	....	....	....	Mar. 29	63,900
Gaines Landing....................	1.8	2,000	3.0	.7	Mar. 29	7,600
Below Gaines Landing..............	1.8	660	3.0	.7	Mar. 29	2,500
Below Gaines Landing (break in levee)........	....	1,000	....	.6	Mar. 29	....
Below Gaines Landing..............	0.5	2,600	3.0	.7	Mar. 29	2,700
Do..........	Slack.	2,600	....	.6	Mar. 29	....
Above Point Comfort..............	0.66	10,000	3.0	.7	Mar. 29	14,000
Pa-toria to Luna (four breaks)	1.5	1,000	1.0	.7	Mar. 29	10,000
Whisky Chute	1.0	330	3.0	.7	Mar. 30	700
Ford and Spears..............	7.0	450	2.0	.7	Mar. 30	4,400
Do..........	3.0	200	7.0	.7	Mar. 30	3,000
Rose Bank..............	0.8	330	3.5	.7	Mar. 30	600
Matthews Bend..............	1.0	330	1.0	.7	Mar. 30	200
Do..........	....	....	....	....	Mar. 30	8,000
Total..............	....	....	....	....	....	117,600

Ashton to Delta, maximum stage.

[Observation by J. B. Johnson.]

FIRST ESTIMATE.

Locality.	Velocity.	Width.	Depth.	Coefficient.	Date of observation.	Maximum stage.	Date of break.	Outflow.
Ashton	0.75	15,000	4.0	.65	Mar. 20	Mar. 20	Old	29,000
Alsatia	10.0	165	12.0	.7	Mar. 21	Mar. 21	Mar. 21	14,000
Do	10 0	660	10.0	.7	Mar. 21	Mar. 21	Mar. 21	46,000
Salem to Rolla (six breaks)	4.0	1,980	12.0	.7	Mar. 21	Mar. 21	....	67,000
Rolla to Mrs. Bell's (seven breaks)	4.0	1,320	4.0	.7	Mar. 21	Mar. 21	....	15,000
Mrs. Bell's to Point (five breaks)	4.0	1,000	3.0	.7	Mar. 21	Mar. 21	....	8,000
Montgomery to Burn's (two breaks)	4.0	330	2.0	.7	Mar. 21	Mar. 21	....	2,000
Omega to Buckhorn (seven breaks)	4.0	3,600	8.0	.7	Mar. 21	Mar. 21	Mar. 13, 17	81,000
Milliken's Bend	5.0	1,300	8.0	.7	Mar. 21	Mar. 21	....	86,000
Total	......	......	......	......	......	......	......	298,000

SECOND ESTIMATE.

Locality.	Velocity.	Width.	Depth.	Coefficient.	Date of observation.	Maximum stage.	Difference of stage.	Date of break.	Outflow.
Ashton	0.75	15,000	2.0	.65	Mar. 30	Mar. 20	2.0	Old	15,000
Alsatia to Goodrich's (three breaks)	5.0	3,300	8.0	.7	Mar. 30	Mar. 21	4.0	Mar. 21	92,000
Above Edgemont (three breaks)	3.0	1,300	4.0	.7	Mar. 30	Mar. 21	4.0	....	11,000
At Rolla's	3.0	480	4.0	.7	Mar. 30	Mar. 21	4.0	....	4,000
Rolla to Mrs. Bell's (five breaks)	1.0	2,140	1.0	.7	Mar. 30	Mar. 21	....	....	2,000
Rolla to Mrs. Bell's (four breaks)	0.0	660	0.0	....	Mar. 30	Mar. 21	....	....	....
Mrs. Bell's to Willow Point (three breaks)	0.0	650	0.0	....	Mar. 30	Mar. 21	....	....	....
Willow Point to Delta	4.0	5,200	6.5	.7	Mar. 30	Mar. 21	1.5	....	95,000
Total	......	......	......	......	......	......	......	....	219,000

Delta to Red River.

[Observation by Hunter Stewart and J. B. Johnson.]

Locality.	Velocity.	Width.	Depth.	Coefficient.	Date of observation.	Date of break.	Outflow.	Summation.
Upper side of Delta	4.0	1,200	1.0	.7	Apr. 1.	....	3,400	
Lower side of Delta	....	....	....	....	Apr. 1.	....	— 3,400	3,400
Below Delta (2 breaks)	1.5	250	4.0	.7	Apr. 1.	....	1,000	
Vicinity of Brown and Johnson's (old break)	1.5	13,000	3.5	.7	Apr. 1.	....	48,000	
Castleman's to Hico	2.0	17,500	4.0	.65	Apr. 1.	....	91,000	140,000
Hico to Sargents	1.5	15,000	3.5	.65	Apr. 1.	....	— 51,000	
Killakranka (breaks)	4.0	165	1.5	.7	Apr. 1.	......	— 700	
Just below Killakranka	4.0	330	3.0	.7	Apr. 1.	......	— 2,800	
Harper Bayou	7.0	200	24.0	.8	Apr. 1.	....	— 27,000	
Between Harper Bayou and the ends of the levee	....	430	....	....	....	Mar. 13.	— 2,000	
Buckner's (2 breaks)	4.0	250	8.0	.7	Apr. 1.	....	— 2,100	
								56,400

Delta to Red River—Continued.

Locality.	Velocity.	Width.	Depth.	Coeffi-cient.	Date of obser-vation.	Date of break.	Out-flow.	Sum-mation.
Point Pleasant	4.0	330	20.0	.7	Apr. 1.	....	18,000	
Do	5.0	250	6.0	.7	Apr. 1.	....	5,000	
Do	4.0	165	1.0	.7	Apr. 1.	....	500	
Lower side of Point Pleasant	0.7	2,000	3.0	.7	Apr. 1	....	3,000	
								82,900
Buckridge	0.7	2,600	2.5	.7	Apr. 1.	Mar. 5.	—3,200	
								79,700
Between Buckridge and Ship's Bayou	5.2	330	8.0	.7	Apr. 2.	....	9,600	
Half a mile above Hard Times	1.4	950	12.0	.7	Apr. 2.	....	11,200	
Hard Times to Deshroon's	9.0	130	8.0	.7	Apr. 2.	....	4,400	
Do	1.2	120	9.5	.7	Apr. 2.	....	1,000	
Do	1.5	50	6.0	.7	Apr. 2.	....	300	
Above Hardscrabble	3.3	250	9.0	.7	Apr. 2.	....	5,200	
At Hardscrabble	5.0	330	8.0	.7	Apr. 2.	....	9,200	
Bondurant	3.0	330	7.5	.7	Apr. 2.	....	5,200	
Kempe	....	....	....	....	Apr. 2.	....	1,200	
Water Proof, break in new levee	3.0	660	10.0	.7	Apr. 2.	Mar. 21.	13,900	
Water Proof, break in old levee	6.0	400	8.0	.7	Apr. 2.	Mar. 21.	13,400	
Water Proof (3d break)	8.5	350	45.0	.7	Apr. 2.	Mar. 21.	93,700	
Hole in the Wall	1.3	260	3.0	.7	Apr. 3.	....	700	
								248,700
Upper arm of Lake Concordia, over the levee and through breaks	2.5	35,000	1.0	.7	Apr. 3.	Mar. 24.	—87,500	161,200
Lower arm of Lake Concordia	2.5	25,000	1.0	.7	Apr. 3.	Mar. 24.	62,500	223,700
From the end of the Henderson and Ashley levee to Grand Cut-off, 35 miles, at 5,000 cubic feet per second per mile—returning to river	1.0	175,000	1.0	....	Apr. 3.	....	—175,000	48,700

Examination of the right bank of the Mississippi River from the mouth of Red River to Donaldsonville, flood of 1882.

[Observation by Hunter Stewart.]

Locality.	Velocity.	Width.	Depth.	Coeffi-cient.	Date of obser-vation.	Out-flow.	Sum-mation.
Red River Landing	3.0	250	7.0	.7	Apr. 4.	3,700	
Do	2.0	100	6.0	.7	Apr. 4.	1,000	
							4,700
Hog Point	2.0	40	2.5	.7	Apr. 4.	200	
Do	1.0	130	5.0	.7	Apr. 4	500	
Do	3.0	200	2.5	.7	Apr. 4.	1,000	
Do	2.0	150	5.0	.7	Apr. 4.	1,000	
Do	3.0	200	5.0	.7	Apr. 4.	2,100	
							9,500
Morganza—crevasse proper	4.5	800	22.0	.7	Apr. 5.	55,400	
Between channel of the crevasse and the ends of the levee	2.0	3 300	10.0	.7	Apr. 5.	46,200	111,100
Point Coupee	7.5	2,200	10.0	.7	Apr. 6.	115,500	226,600

Examination of the Arizona and Landry crevasses, Louisiana, flood of 1882.

[Observation by Hunter Stewart.]

Locality.	Velocity.	Width.	Depth.	Coeffi-cient.	Date of observ-ation.	Out-flow.	Sum-mation.
Arizona, Iberville Parish	10.0	1,000	4.0	.7	Apr. 7	28,000	
Landry, Ascension Parish	6.6	123	5.0	.7	Apr. 6	3,000	
							31,000

4.—SAINT FRANCIS FRONT, THE YAZOO FRONT, AND A PORTION OF THE TENSAS FRONT, FOR FLOOD OF 1883.

(With an approximate determination of the discharge of the Saint Francis and Yazoo rivers, by Hunter Stewart, United States assistant engineer. Party of Hunter Stewart and Homer P. Ritter, United States assistant engineers.)

SCOPE OF WORK.

The work contemplated in the letter of instructions of February 25, consisted of an examination and an approximate determination of the amount of water escape from the Mississippi River over the following portions of its banks: The Saint Francis Front, or the right bank from Commerce, Mo., to Helena, Ark., the Yazoo Front, or the left bank from Horn Lake to Vicksburg, and the Tensas Front, or the right bank from the mouth of Cypress Creek to the mouth of Red River.

This was afterwards amended by the letter of instructions of March 13, which limited the examination of the Tensas Front to that portion of it which lies above Delta, La.

OUTFIT.

The steamer S. C. Baker, equipped with a single crew, was assigned for this service. The engineer force consisted of Messrs. Hunter Stewart and Homer P. Ritter, United States assistant engineers. I take pleasure in acknowledging the efficient and valuable services rendered by Mr. Ritter.

JOURNAL.

Monday, February 26, 1883: The party left Saint Louis on board the steamer S. C. Baker at 6 p. m.

Tuesday, February 27: This day was consumed in making the run from Carondelet to Daniel's Landing.

Wednesday, February 28: Arrived at Cairo at 8 a. m; coaled steamer. Left Cairo at 1 p. m., examined the right bank from the upper side of Bird's Point to the lower portion of Lucas Bend.

Thursday, March 1: The examination of the right bank was continued; that portion lying between the lower portion of Lucas Bend and Lazelle's Landing was gone over.

Friday, March 2: The portion of the Saint Francis Front situated between Lazelle's Landing and Osceola was examined.

Saturday, March 3: Coaled steamer at Plum Point. The work extended from Osceola to Eldorado.

Sunday, March 4: The examination of the right bank was carried to Hopefield Point. Proceeded to Memphis, and telegraphed the office as per instructions. Found the river rising at Memphis; lay there the rest of the day.

Monday, March 5: Lay all the morning at Memphis. At 12 m., finding that the rise during the previous six hours was slight, left port at 1 p. m. Examined the right bank from Hopefield to Graves Bayou. Arrived at Norfolk Landing at 5 p. m.; ascertained that the river had risen 7 inches between the morning of the 3d and the morning of the 5th instant, and was continuing to rise. Lay at Norfolk Landing during the night.

Tuesday, March 6: Lay here all day, as the river continued to rise.

Wednesday, March 7: The rise at Norfolk Landing during the night of the 6th and 7th was but slight, and the news from Memphis indicated that the recent rise was caused by the outflow from the Saint Francis Basin. Examined the right bank from Graves Bayou to Ashley Point, and the left bank from Norfolk Landing to Mhoon's Landing.

Thursday, March 8: The right bank was examined from Ashley Point to the mouth of the Saint Francis River, and the left bank from Mhoon's Landing to Short Stop. The discharge of the Saint Francis River was measured at a point about 2¼ miles above its mouth.

Friday, March 9: The examination of the Saint Francis Front was completed. The section of the Yazoo Front comprised between Short Stop and Glendale was reconnoitered; the levees were followed systematically.

Saturday, March 10: The examination of the Yazoo Front was continued. The levees were followed from Glendale to Friars Point.

Sunday, March 11: The examination of the Yazoo Front was continued and carried to Sunflower Landing.

Monday, March 12: The examination of the Yazoo Front was continued. The crevasse at Gilchrist, 3 miles below Australia, was gauged. Inquiries concerning the state of the levees were made, and they were reported and found to be safe to Mound Place. The examination of the Tensas Front was commenced, and that portion situated between the mouth of Cypress Creek and Arkansas City was inspected, and the discharge along it gauged.

Tuesday, March 13: On the Yazoo Front the levee was reported and found to be

intact to Greenville. On the Tensas Front the examination was carried to Leland's

Wednesday, March 14: The Tensas Front was examined from Leland's to Wilson's Point. On the Yazoo Front the levees were safe.

Thursday, March 15: Coaled steamer. The Elleslie crevasses, on the Yazoo Front, were examined, and the examination of the Goodrich crevasse, on the Tensas Front, was commenced.

Friday, March 16: The examination of the Goodrich crevasse was completed. The levees on the right bank were reported intact to Delta; the Yazoo River was gauged; proceeded to Vicksburg, where orders were received to discontinue the work. The steamer S. C. Baker was turned over to the captain of the same, as per instructions.

METHODS OF OBSERVATIONS.

The method of observation varied with the character of the outlet. The channels may be classified as follows:

1. Over the natural surface of the bank.
2. Over the top of the levee.
3. Through a crevasse in the levee.
4. Through open streams.

(1.) *Over the natural surface of the bank.*—The mode of observing for this character of outlet is described in the report on the examination of the Saint Francis Front for the flood of 1882. No material change was made this year, with the exception of the omission of the measurement of the water flowing directly over points—that is, leaving the river on the upper side, to return immediately on the lower side, without any increase or diminution of volume. The action of the flood of 1882 indicated where this could be safely done.

(2.) *Over the top of the levee.*—For the determination of the discharge occurring over the top of the levee, frequent soundings were taken, the velocity was measured with the log, and the length of submergence with the stadia. When the distance was too great to be measured, or the bends in the levee or thickness of the underbrush prevented the use of the stadia, then the length of overflow was estimated. Whenever there was an important change either in the depth or the velocity of the escaping water, the distances applicable to the other elements of discharge were estimated. The depth and velocity for continuous submergence of the levee were found to remain very nearly uniform. This may be due to the fact that the levees were built to a grade which is, presumably, equal to the slope of the river at high water, and that there was but little variation in the fall of the water.

(3.) *Crevasse in the levee.*—The discharge of a crevasse was obtained by measuring its width with the stadia, its surface velocity with the log, and determining its mean depth by sounding a cross-section, the number of soundings varying with the size of the crevasse. There are in the tabulation two discharges which were not obtained by direct measurement or observation—the Horn Lake crevasses on the Yazoo Front, and the Luna crevasse on the Tensas Front. A personal inspection of these was omitted on account of the reliable information received concerning them.

(4.) *Open streams.*—In the case of small open streams, a cross-section was sounded, the soundings being placed approximately equidistant, the surface velocity was measured with the log, and the width was estimated.

In the gauging of the Saint Francis and Yazoo rivers, the soundings were located either with the stadia or with the transit, the velocity was obtained by means of rod-floats, and the width of the cross-section was determined by stadia measurement.

COMPUTATION.

The following formula is used in computing discharge:

$$Q = V \times W \times S \times C;$$

Wherein:

Q = discharge.
V = measured velocity.
W = width of cross-section.
S = mean depth of cross-section.
C = coefficient of reduction.

The following is a list of coefficients generally used in the computations:

For open streams, mean velocity = surface velocity $\times$ .8.

For crevasses and flow over the levee, mean velocity = surface velocity $\times$ .7.

For discharge over the bank, mean velocity = surface velocity $\times$ .7; and effective area = measured area $\times$ .9.

$$Q = V \times W \times S \times C, \text{ where, } C = .65,$$

In special cases other coefficients are used—for instance, for the escape in Beckwith's Bend (Saint Francis Front) .5 is used, owing to the great amount of drift

which was banked up against the timber, and in the computation of the discharge of the Yazoo River, a coefficient of .92 is used to reduce measured to mean velocity on account of the immersion of the rod-floats.

STAGE OF RIVER.

A table is given below of the relation of the stages of the floods of 1882 and 1883 from Cairo to Vicksburg; also the relation of the stage at which the observations were made to that of the maximum stage of this year, giving the respective dates.

Cairo to Vicksburg (flood stages).

Locality.	Date of observation flood of 1883.	Date of maximum stage, 1883.	Maximum stage, 1883, ref. maximum stage, 1882.		Observation stage, 1883, ref. maximum stage, 1883.	
			+	−	+	−
			Feet.	*Feet.*	*Feet.*	*Feet.*
Cairo, Ill	Feb. 28	Feb. 27	0.30			0.09
Widow Mercer's, Mo	Feb. 28	Feb. 27	0.33			0.08
O'Bryan's, Mo	Feb. 28	Feb. 27	0.58			
Belmont, Mo	Mar. 1	Feb. 27	0.48			0.27
Salmon's, Ky	Mar. 1	Feb. 28	0.38			
Hickman, Ky	Mar. 1	Feb. 26	0.32			
Saint James Bayou, Mo	Mar. 1	Feb. 27	0.46			
Lester's, Ky	Mar. 1	Feb. 28	0.50			
Donaldson's Point, Mo	Mar. 1	Feb. 28	0.33			
Morrison's Landing, Mo	Mar. 1	Mar. 1	0.25		0.00	0.00
Tonsy's Landing, Mo	Mar. 1	Feb. 27	0.17			
Point Pleasant, Mo	Mar. 1	Feb. 28	0.33		0.00	0.00
Batsell's Landing, Mo	Mar. 2					0.17
Cottonwood Point, Mo	Mar. 2	Feb. 28	0.17			0.15
Buckner's Landing, Mo	Mar. 2	Feb. 26	0.23			
Fulton, Tenn	Mar. 3	Mar. 1, 2		0.54	0.00	0.00
Mouth Hatchee River, Tenn	Mar. 3			0.60		
Randolph, Tenn	Mar. 3			0.50		
Pecan Point, Mo	Mar. 3	Mar. 1	0.06			
Thomas Landing, Tenn	Mar. 3	Feb. 28	0.00	0.00		
Redman's Landing, Mo	Mar. 4	Mar. 4	0.13		0.00	0.00
Memphis, Tenn	Mar. 5	Mar. 6–8		0.40		0.06
Norfolk Landing, Miss	Mar. 7	Mar. 9		0.58		0.17
Commerce Landing, Miss	Mar. 7			0.42		
Mhoon's Landing, Miss	Mar. 7	Mar. 7, 8		0.60	0.00	0.00
Bordeaux Point, Miss	Mar. 8	Mar. 10		0.67		
Austin, Miss	Mar. 8	Mar. 8		0.35	0.00	0.00
Helena, Ark	Mar. 10	Mar. 8, 9		0.30		0.05
Delta, Miss	Mar. 10	Mar. 6		0.42		0.05
Saint Louis Landing, Ark	Mar. 11	Mar. 10	0.04			
Sunflower Landing, Miss	Mar. 11	Mar. 10, 11	0.16		0.00	0.00
Pushmataha, Miss	Mar. 12		0.12		0.00	0.09
Australia, Miss	Mar. 12	Mar. 10	0.04			0.25
Gilchrist's, Miss	Mar. 12	Mar. 10	0.04			0.30
Laconia, Ark	Mar. 12	Mar. 10	0.17			
Concordia, Miss	Mar. 12			0.32		0.33
Cumbyville, Ark	Mar. 12	Mar. 9–12		0.40	0.00	0.00
Riverton, Miss	Mar. 12	Mar. 11		0.42		0.06
Ozark Island, Ark	Mar. 12	Mar. 11		0.33		
Niblett's, Miss	Mar. 12	Mar. 10		0.67		0.12
Bolivar, Miss	Mar. 12	Mar. 10		0.47		
Catfish Point, Miss	Mar. 12	Mar. 11		0.92		0.04
Eutaw, Miss	Mar. 12	Mar. 8		0.50		
Mound Place, Miss	Mar. 12	Mar. 11		1.08	0.00	0.00
Arkansas City, Ark	Mar. 12	Mar. 11		0.75		0.05
Gaines Landing, Ark	Mar. 13	Mar. 12		0.40		0.06
Llewellyn's, Ark	Mar. 13	Mar. 12		0.58	0.00	0.00
Luna Landing, Ark	Mar. 13	Mar. 12		0.58	0.00	0.00
Greenville, Miss	Mar. 13	Mar. 10–12		1.32		0.06
Leland's, Ark	Mar. 14	Mar. 11		0.80		
Refuge, Miss	Mar. 14	Mar. 16		1.17		
Glenora, Miss	Mar. 14	Mar. 25		0.50		
Ross Landing, Ark	Mar. 14	Mar. 10		1.17		
Ashton, La	Mar. 14	Mar. 14		1.00	0.00	0.00
Wilson's Point, La	Mar. 14	Mar. 14		2.40	0.00	0.00
Lake Providence, La	Mar. 15	Mar. 11–14		1.85		0.05
Elleslie, Miss	Mar. 15	Mar. 14		1.85		0.05
Goodrich's, La	Mar. 16			2.50	0.00	0.00
Vicksburg, Miss	Mar. 16	Apr. 7		4.95		0.75

SAINT FRANCIS FRONT, COMMERCE, MISSOURI, TO HELENA, ARKANSAS. GENERAL DESCRIPTION OF OVERFLOW.

From Commerce, Mo., to within five miles of Bird's Point, there was no appreciable escape from the river. On the upper side of Bird's Point there was a large quantity of water leaving the river, the greater part of which returned between Bird's Point and O'Bryan's. A portion of O'Bryan's farm was above overflow. From O'Bryan's to the lower portion of Lucas Bend there was a large escape, while from the upper side of Belmont Point to nearly midway of Wolf Island chute there was considerable return flow. There was some escape in the lower portion of Wolf Island Chute, and quite a volume of water leaving the river in Beckwith's Bend, and there was a continuous return flow from chute of Island No. 6 to the middle of the bend of Island No. 8. From the lower portion of the bend of No. 8 to the upper side of Donaldson's Point, a large escape took place, while there was a vast quantity of water returning to the river between Donaldson's Point and New Madrid. From a short distance below New Madrid to the head of Island No. 11, the bank was exposed; from Point Pleasant to Phillips' Landing the bank was overflowed; Ruddle's Point was exposed.

From Stewart's Landing to Craighead Point there was a continuous submergence of the natural bank, but there was not a movement in the overflow for all of the distance, owing to the action of the levees in the rear. In the vicinity of Gayoso there was a return flow during the maximum stage of the flood of 1883, while at the observation stage, and presumably at the maximum stage of the flood of 1882, there was an escape from the river. In the bend of Island No. 34 there were only three small crevasses. Morgan's Point was submerged on the upper side with no current in the overflow, the point itself was exposed, and on its lower side there was a slight submergence. There was no escape or return flow in the bend of No. 35. From Hampson and Ferguson's to Pecan Point the bank was mostly out of water. From Pecan Point down McGavock chute, and round the old bend of Island No. 37 to Viola Landing, the right bank was 2 feet out of water. From Viola Landing to Pacific Landing there was no overflow. From Turner's woodyard to Hopefield there was a continuous overflow. There was one break in the levee on the lower side of Hopefield Point, and another at about the middle of President's Island Bend, through both of which the water was flowing into the river.

At McConnell's Landing the land was mostly out of water, but where it was overflowed there was an escape taking place. From McConnell's to Reeves' the levee was not submerged. At Harris' and below Scanlan's, the overflow was stationary. In Cow Island Bend there was a slight escape, and the levee in the rear of Cat Island was intact. From Harcklerode's to Helena there was a continuous overflow. The Saint Francis River was gauged at a point about 2¼ miles above its mouth, where the right bank was exposed.

The examination was closed by observing the movement of the overflow along the left bank of the Saint Francis from the location of the discharge section to its mouth.

RESULTS.

	Cubic feet per second.
Net escape or probable error, Commerce to New Madrid	45,000
Summation for section below New Madrid	
Escape to Phillips'	50,000
Return flow, vicinity of Stewart's Landing	10,000
Net escape at Batsell's Landing	40,000
Escape Batsell's to Island No. 14	90,000
Escape at Island No. 14	130,000
Return flow, Gayoso	95,000
Net escape, Gayoso	35,000
Escape, Bell's Point to Wright's Point	175,000
Net escape to Wright's Point	210,000
Return flow, Barfield	25,000
Net escape, Barfield	185,000
Escape from Barfield to Daniel's Point	48,000
Escape from Daniel's Point to Lanier's	78,000
Net escape at Lanier's	311,000
Return flow, Bend of No. 35	2,000
Net escape to Pecan Point	309,000
Escape, Fogelman's Chute to Hollybush Landing	64,000

	Cubic feet per second.
Net escape at Hollybush Landing	373,000
Return flow, vicinity of Mound City	18,000
Net escape at Mound City	355,000
Escape, Mound City to Hopefield	58,000
Net escape at Hopefield	413,000
Return flow, Hopefield to McConnell's	17,000
Net escape above McConnell's	396,000
Escape, McConnell's to Graves Bayou	13,000
Net escape at Graves Bayou	409,000
Net escape between Graves Bayou and Excelsior P. O	24,000
Net escape at Council Bend	433,000
Return flow in Council Bend	76,000
Net escape at Johnson's Landing	357,000
Escape from Johnson's Landing to Walnut Bend	114,000
Net escape, head of Walnut Bend	471,000
Return flow, Walnut Bend	99,000
Net escape, foot of Walnut Bend	372,000
Return flow, Walnut Bend to mouth of Saint Francis River	139,000
Net escape at the mouth of Saint Francis River	233,000

The ridge on which New Madrid is situated was not covered either by the flood of 1882 or by that of 1883. The town of New Madrid was submerged during both of these floods, but its site is not on the crest of the ridge. It has also been learned from reliable information of residents of this section that little, if any, overflow water escaped over or through this ridge into the lower section of the Saint Francis Bottoms. In view of this fact, taken in connection with the uncertainty of the escape of any overflow water through the depression between Big Prairie and the Commerce high land, the net escape of 45,000 cubic feet per second above New Madrid, as obtained from the observations, is not included in the summation of net escape for points below. In this connection there is another fact to be taken into account, which is, that the quantity of 45,000 cubic feet per second represents a very small probable error in the measurement, by such methods as were used, of 1,870,000 cubic feet per second, which is the arithmetical sum of the movement of overflow taking place over the bank of the river between Commerce and New Madrid.

SAINT FRANCIS RIVER.

	Cubic feet per second.
Measured discharge	373,000
Supply from the net escape from Mississippi River	233,000
Supply from other sources, or excess of discharge	140,000

The discharge of the Saint Francis River as given by the observations of March 8, 1883, is greatly in excess of its estimated discharge at the maximum stage of the flood of 1882, as made in the report upon the same.

The maximum stage of 1883, at the discharge section, was reported to be 1 foot below the maximum stage of 1882, and the reconnaissance of the Saint Francis during the flood of 1882 was made at a stage .8 foot below the maximum of that year, so that the actual stages of the two examinations were very nearly equal. The estimate of the discharge for 1882 was, to a certain extent, based upon the discharge observation made at Madison, as there was no available outfit for gauging the Saint Francis near its mouth; a section was sounded at about the same place where the discharge was observed in 1883, and the velocity was estimated by its apparent relation to the measured velocity at Madison.

The greater velocity of the river during the flood of 1883 was very noticeable.

The excess of the output of the Saint Francis over the net escape from the Mississippi River may represent the amount contributed by the tributaries of the Saint Francis, or these plus the error of the flood observations, or it may be due to the fact that the Saint Francis actually carried the escaping water at a more rapid rate owing to the comparatively low stage at its mouth.

The following table of change of stage shows that a very great amount of water

was discharged by the Saint Francis River, from whatever source it was received, for from March 1–9 the river oscillated 15 foot at Memphis, rose 2.5 feet at Mhoon's, and 3.3 feet at Helena. Thus after the crest of the flood wave, as propagated down the river channel proper, had reached Memphis, and a fall had set in, the rise from the Saint Francis caused an increase of stage in the Mississippi as far above its mouth as Memphis.

Table of change of stage.

[illegible]	Memphis.		Mhoon's.		Helena.	
	Change.	Feet.	Change.	Feet.	Change.	Feet.
March 1	Rise.	0.05	Rise.	0.03	Rise.	0.15
2	Fall.	0.05	Rise.	0.16	Rise.	0.25
3	Stationary.	0.00	Rise.	0.14	Rise.	0.35
4	Stationary	0.00	Rise.	0.72	Rise.	0.75
5	Rise.	0.10	Rise.	0.70	Rise.	1.05
6	Rise.	0.05	Rise.	0.40	Rise.	0.50
7	Stationary.	0.00	Rise.	0.30	Rise.	0.15
8	Stationary	0.00	Rise.	0.05	Rise.	0.10
9	Fall.	0.15	Fall.	0.07	Stationary.	0.00

Saint Francis Front, 1883.—*Table of water escape of 1883 over that portion of the right bank of the Mississippi River forming the front of the Saint Francis Bottom (Commerce, Mo., to Helena, Ark.).*

[ABBREVIATIONS: V, surface velocity in feet per second. W, width, in feet, of the cross-section to which V and S are applied. S, soundings in feet. C, coefficients used to reduce V to mean velocity and to correct cross-section area for obstructions. Z, magnetic azimuth of the direction of the current. A, direction of current; f, from river, t, toward river; p, parallel. Q, escape in cubic feet per second; with minus sign it indicates return flow. Q'', net escape in cubic feet per second.]

Date.	No.	Locality.	V	W	S	C	Direction. Z	Direction. A	Q	Q''
1883							°			
Feb. 28	A	Above Railroad transfer	......	......	......	......	......		25,000	
28	1	Railroad transfer above Bird's Point.	1.6	6,400	9.5	.65	280	f	63,200	
28	2	Upper side of Bird's Point.	3.3	5,000	11.0	.65	260	f	118,000	216,200
28	3	Above old Norfolk Landing.	1.1	3,000	5.0	.65	......		—10,700	
28	4	Widow Mercer's	1.0	7,500	6.5	.65	205		—31,700	
28	5	1½ mile below Norfolk Landing.	1.2	11,000	8.0	.65	280		—68,600	
29	6	Just above O'Bryan's	1.0	6,000	0.5	.65	S		—37,000	68,200
28	7	Just below O'Bryan's	3.3	5,600	0.0	.65	70	f	108,100	
28	8	Jarr's	2.5	9,700	7.0	.65	S	f	110,300	
28	9	Lower portion Lucas Bend	2.3	10,400	7.0	.65	345	f	108,600	395,400
Mar. 1	10	½ mile above Belmont	1.4	10,400	7.0	.65	275	t	—60,200	
1	11	½ mile below Belmont	0.6	7,500	4.5	.65	325	t	—13,200	
1	12	Upper portion Wolf Island Chute.	0.7	14,000	5.0	.65	S	t	—31,900	264,100
1	13	Middle of Wolf Island Chute.	......	......	......	......	......	......	......	
....	14	Lower portion Wolf Island Chute (over levee).	1.0	8,000	1.0	......	......	f	8,000	
1	15	Q Beckwith's	2.5	......	9.0	......	......	p, w	......	
1	16	Farris Landing	1.7	6,000	4.0	......	75	f	26,500	
1	17	Middle of Beckwith's Bend.	1.5	10,000	10.0	.5	......	f	75,000	
1	18	Sam Parker's	1.6	8,000	4.0	.65	40	f	33,300	426,900
1	18a	Chute of Island No. 6	1.5	14,000	......	.65	......	......	—21,000	
1	19	Below foot of Island No. 6	0.6	9,000	6.0	.65	25	t	—21,100	
1	20	......	0.8	12,500	5.5	.65	41	t	—35,800	
1	21	......	1.5	9,000	7.0	.65	45	t	—61,400	
1	22	Just above Saint James Bayou.	1.2	4,300	6.5	.65	25	t	—28,500	
1	23	Saint James Bayou	1.8	110	3.4	7	45	t	— 3,400	
1	24	Bend of No. 8	0.3	8,500	5.5	.65	S	t	— 9,100	
1	25	Middle of Bend No. 8	1.0	14,500	6.5	.65	29	t	—61,300	185,300

Saint Francis Front, 1883.—Table of water escape of 1883, &c.—**Continued.**

Date.	No.	Locality.	V	W	S	C	Direction. Σ	Direction. ▲	Q	Q''
1883.							5			
Mar. 1	26	Lower portion Bend No. 8	2.0	12,900	6.5	.65	100	f	109,000	
1	27	Phillips	0.8	11,400	5.5	.65	80	f	32,600	
1	28	Opposite Lester's	1.0	8,800	6.5	.65	74	f	46,600	
1	29	Opposite State line	1.4	5,300	6.5	.65	5	f	31,300	
1	30	Judge Riley's	2.6	4,100	7.0	.65	90	f	46,500	
										455,300
1	30a	Donaldson's Point	1.5	10,400	7.5	.65	......	t	—76,100	
1	31	Attiberry's	1.0	8,900	7.5	.65	115	t	—43,400	
1	32	C. A. Lafarge	1.0	8,700	11.0	.65	101	t	—63,200	
1	33		1.0	11,800	13.0	.65	80	t	—99,700	
1	34	Morrison's	1.0	17,000	8.5	.65	55	t	—93,900	
1	34a	Saint John's Bayou						t	— 8,000	
1	35	Little or Dry Bayou	2.1	50	16.0	0.8	30	t	— 1,600	
1	35a	Vicinity of Dry Bayou	3.0	1,200	16.0	.65	30	t	—25,000	
1	35b	Town of New Madrid	Slack		2.5					
		Net escape or probable error above New Madrid.								45,400
1	36	Point Pleasant to Phillips'	1.1	15,000	4.6	.65	60	f	48,300	
1	37	Phillips	1.7	500	2.5	.65	66	f	1,409	
										49,700
2	38	Above Cushion Lake Bayou	0.2	6,000	4.0	.65	350	t	— 7,900	
2	39	Cushion Lake Bayou	0.2	50	22.0	0.8	90	t	— 200	
2	40	Stewart's Landing	0.5	1,500	4.0	.65	5	t	2,000	
										39,700
2	41	Batsell's Landing	1.3		5.5		50	p. w		
2	42		1.3	14,000	5.0	.65	30	f	59,100	
2	43	Above Island No. 14	1.7	14,000	3.0	.65	20	f	30,900	
										129,700
2	44	Below Island No. 14	1.0	7,000	6.0	.65	115	t	—27,300	
2	45	Above Gayoso	0.8	5,000	9.0	.65	325	t	—28,400	
2	46	Bayou at Gayoso	2.3	250	11.0	0.8	325	t	— 5,100	
2	47	Below Gayoso	2.0	6,000	5.0	.65	341	t	—39,000	
										34,900
2	48	Bell's Point	1.7	6,000	2.0	.65	36	f	13,300	
2	48a	Chute of Islands 16 and 17 (estimated).						f	35,000	
2	49	Head of chute Island No. 18	Slack		5.0					
2	50	Chute of Island No. 18	Slack		4.0					
2	51	do	1.4	2,000	3.0	.65	71	f	5,500	
2	51a	Half Moon Bayou	Slack							
2	52	Foot of chute of Island No. 18.	1.5	500	3.0	0.7	......	f	1,600	
2	52a	Over levee	0.8	14,000	1.0	0.7		f	7,800	
2	52b	Jackson's Store to Midway	1.5	14,000	3.0	.65	......	f	40,900	
2	53	Midway Landing	2.6	150	4.5	0.7	57	f	1,100	
2	54	Below Hoffman's Landing	1.7	7,300	3.0	.65	46	f	24,200	
2	55	Hickman's Landing	1.3	9,500	2.5	.65	349	f	20,100	
2	56	Wright's Point	1.3	12,000	2.5	.65	300	f	25,400	
										209,800
2	57	Buckner's Landing	0.4	9,000	3.0	.65	4	t	— 7,000	
2	58	Barfield Landing	1.0	6,000	4.5	.65	285	t	—17,500	
										185,300
2	59	1¼ miles below Barfield	1.3	6,000	4.0	.65	60	f	20,200	
2	60	O'Donnel's Landing	Slack		4.0					
2	61	Canadian Reach	1.4	5,200	7.5	.65	76	f	35,500	
										241,300
2	62	½ mile above Daniel's Point	0.7	6,000	3.0	.65	256	t	—8,200	
										232,200
2	63	Fletcher's Landing	0.7	8,600	4.5	.65	109	f	17,600	
2	63a	Below Elmot	1.5	9,500	2.5	.65		f	23,200	
3	64	Sans Souci	2.8	100	2.0	.7	45	f	400	
3	64a	Vicinity of Tansas Landing	1.5	4,000	1.0	.7	45	f	4,200	
3	64b	Craighead Point	1.5	10,000	3.0	.65	....	f	29,300	
3	65	Lanier's	2.7	550	3.0	.7	35	f	3,100	
										310,000
3	66	Preston's Landing	1.0	1,000	1.0	.65		t	—600	
3	67	Hampson's	0.2	4,000	2.0	.65	28	t	—1,000	
										309,000
3	71	Just above Turner's wood-yard	0.3	7,500	2.0	.65	30	f	2,900	
3	72	Middle of Fogelman's Chute	1.2	9,000	1.5	.65	60	f	10,500	
3	73	Foot of Fogelman's Chute	1.3	7,500	2.5	.65	25	f	18,700	
										330,100
4	74	Eldorado	Slack							
4	76	James'	Slack		3.5					
	77	Stroutman's	0.8	11,500	3.5	.65	57	f	20,900	
	78	**Hollybush Landing**	**0.7**	**24,000**	**1.5**	**.65**	**346**	**f**	**16,400**	**373,400**

***Saint Francis Front*, 1883.—*Table of water escape of* 1883, *&c.*—Continued.**

Date.	No.	Locality.	V	W	S	C	Direction Z	Direction A	Q	Q''
1883.							°			
Mar. 4	79	Bayou at Mound City	2.7	160	22.0	.8	251	t	—7,100	
4	80	..... do	0.9	100	6.0	.8	250	t	—400	
4	81	Above Mound City (over levee)	...	7,500	...	......	.....	t	—7,500	
4	..	Break in levee	1.0	200	5.5	.7	290	t	—500	
4	81a	Below Mound City (over levee)	..	2,500	....	....	...	t	—2,500	335,100
4	82	Lower end Chicken Island Chute.	2.6	3,500	1.0	.7	330	f	6,400	
4	83	Upper side of Hopefield Point	1.2	12,000	5.5	.65	355	f	51,500	413,000
4	84	..... do	1.7	5,000	8.0	65	175	t	—16,600	396,400
5	85	Hopefield Point	0.7	3,300	3.0	.65	....	f	4,500	400,900
5	86	Upper portion President's Island Bend	2.9	300	4.5	.7	328	t	—2,700	
5	87	Middle of President's Island Bend	0.6	1,200	4.0	.65	315	t	—1,900	396,300
5	88	Lower portion of President's Island Bend.	1.0	3,500	1.0	7	....	f	2,500	
5	89	1½ miles above Reeve's Landing	Slack	.....	.. ...	....	.....	..	......	
5	90	Harris Landing ...	Slack	.. ..	....	....	...	..	......	
5	91	Scanlan's Landing	Slack		...	..	...	..	....	
5	92	Cow Island Bend	0.6	4,200	1.5	.65	150	f	2,500	
5	93	Vicinity of Graves Bayou	0.8	7,400	2.0	65	192	f	7,700	409,000
7	94	Harckelrode's	1.3	300	2.0	.7	.	t	500	
7	95	Horseshoe Lake Bayou .	2.0	200	10.0	8	321	t	—3,200	
7	96	Below Bayou	1.5	8,000	2.0	.65	317	t	—15,600	389,700
7	96a	4 miles levee	... .	.	..	....	...	f	40,000	
7	97	Excelsior Post-office	0.3	7,000	2.5	.65	130	f	3,400	433,100
7	98	Council Bend	1.0	9,800	7.0	65	......	t	44,500	
7	99	......do	0.8	6,800	4.0	65	.....	t	—18,300	
7	100	......do	0.5	8,200	5.0	.65	......	t	—13,300	356,900
7	101	1 mile above Johnson's Landing.	Slack	. ...	....	....	.....	.	....	- ....
7	102	Johnson's Landing	1.3	5,000	4.0	.65	.... .	f	25,300	
7	102a	Peters	.		....	....	...	...	18,000	
7	103	Upper side Ashley Point ..	1.7	16,000	4.0	.65	......	f	70,700	470,900
8	104	Walnut Bend...... . ..	1.1	5,000	7.0	.65	..	t	—25,000	
8	105	... do	1.3	5,500	7.5	.65	.....	t	—34,900	
8	106	.... do	0.6	6,000	6.5	.65	.. ..	t	—12,700	
8	107	.. do	0.8	4,500	7.0	.65	....	t	—16,400	
8	107a	.... do	1.0	300	9.0	.7	.....	t	—1,900	
8	108	.... do	1.0	2,500	5.0	65	....	t	—8,100	371,900
8	109	. .. do	Slack	... ...	5.5	.. .	....	..	.... .	
8	110	....	0.6	6,500	5.0	.5	....	f, d	8,600	380,700
8	111	Harding's Point crossing point from upper side.	1.0	. ...	6.5	...	.. .	t	....	
8	112	Upper portion Saint Francis Bend	1.1	9,000	7.5	.65	......	t	—48,300	
8	112a	Chute of Saint Francis Island.	0.3	250	20.0	.8	....	t	—1,200	
8	112b	Saint Francis Bend	0.5	8,000	7.0	65	....	t	—16,200	
8	113	......do	1.2	4,000	8.5	65	......	t	—26,600	
8	114	1½ miles above mouth Saint Francis.	1.2	8,600	8.0	.65	.....	t	—58,700	232,800
9	115	From the discharge section of the Saint Francis River, located 2½ miles above its mouth to the mouth, observations taken over the left bank of the Saint Francis River	1.0	5,000	5.5	.65	......	f	17,900	250,700
9	116		0.9	2,000	6.0	.65	......	t	—7,000	
9	117		1.4	2,000	6.0	.65	......	t	—10,900	282,800
		Net escape from New Madrid exclusive of the amount of overflow water returned by the Saint Francis River.	..	.	......	......	......	....	....	233,000

Discharge of the Saint Francis River, March 8, 1883.

Partial cross-section areas, square feet.	Measured velocity, feet per second.	Partial discharge, cubic feet per second.
11,660	11.5	134,090
15,360	10.0	153,600
13,420	8.7	116,754
7,380	8.3	61,254
47,829	....	465,698

Coefficient to reduce measured velocity to mean velocity, .8; true discharge, 465,698 × .8=372,600 cubic feet per second; cross-section area, 47,820 square feet; width, 835 feet; mean depth, 57.3 feet; mean velocity, 7.8 feet per second. Stage (maximum of 1883) 1 foot below high water, 1882.

The discharge section was located at the Smiley Plantation about 2½ miles above the mouth of the Saint Francis River. The right bank was out of water and the left bank was covered two (2) feet deep. The base line was located on the left bank and was 300 feet long, measured by stadia. Two parallel range lines were located by the prismatic compass. The angle of the discharge section and base line was 89° 30′.

Four rod-floats with 10 feet immersion were run; the time was taken with an ordinary watch. The positions of soundings and their distances were measured by stadia.

YAZOO FRONT.

There were two breaks in the Horn Lake levee which were of the same dimensions as those that occurred during the flood of 1882. These had been roughly repaired by the inhabitants after the subsidence of the flood of last year, but the new work was washed away by the high water of this year. The output was small, and capable of being cared for by the local drains, until the river overflowed the bank between Harklerode's and Star Landing, when it was backed up and overflowed a considerable portion of the De Soto Front. These breaks were not visited, and the estimate of their discharge was made from information received.

A portion of the unleveed bank between Norfolk and Star Landings was barely covered, with no appreciable current in the overflow. This fact will account for the discrepancy in the widths of "outlet for overflowed banks" that exists in the tabulated results of the floods of 1882 and 1883.

The following facts were obtained concerning the action of the river at Norfolk Landing during the high water of February and March, 1883. From February 28 to March 2 the river was stationary; March 2 and 3 there was a slight fall; from 9 a. m. March 3, to 9 a. m. March 5, there was a rise of seven (7) inches; March 5 to 7 there was a continuation of the rise; the exact amount was not measured; March 7 to 9 there was a rise of two inches, the flood reaching its maximum on March 9. This data, taken in connection with the gauge-readings at Memphis, Mhoon's, and Helena, shows the effect of the return flow from the Saint Francis bottoms.

From a short distance below Star Landing to 2½ miles below Commerce, the levee was intact, and for the greater part of this stretch almost entirely exposed on both sides.

The levees were followed from Commerce to Hulberton, or Hughes, with the following results: From 2½ miles below Commerce to 1 mile below Mhoon's Landing there were 49 outlets through which the water was escaping from the river; from 1 mile below Mhoon's to McKinney Bayou (inclusive) there were 11 inlets through which the water was returning to the river; from McKinney Bayou to Glendale there were 45 outlets and 1 inlet, and from Glendale to 2 miles above Hulberton there were 29 outlets.

From Hulberton to 2 miles above Sunflower Landing the levees were intact, but a portion of this tract was submerged by water that escaped above.

The overflow water in the gap of 2 miles just above Sunflower Landing was sounded and found to have no appreciable current. There were reported two crevasses in the levee which joins the line of the second Mississippi levee district with the Totten Ridge. These were not visited, as the water escaping through them had already been gauged.

From Sunflower Landing to the end of the second levee district there were only two localities where the levee had given way; *i. e.*, at Gilchrist's, a short distance below Australia, there was one crevasse, and at Elleslie, opposite Lake Providence, there were three crevasses. These were visited and gauged.

The Yazoo River was gauged at a section a few hundred yards below the debouchure of Steele Bayou.

RESULTS.

The detailed estimates for the discharge of all outlets will be found in the tabulation, which gives:

1. The approximate location of the outlet.
2. The character of the outlet.
3. The surface velocity of the water.
4. The width of the outlet.
5. Mean depth of outlet.
6. Coefficient of reduction.
7. Date of observation.
8. Stage of water at the date of observation, referred to the maximum of 1883.
9. Stage of water at the date of observation, referred to the maximum of 1882.
10. Direction of flow.
11. Discharge and partial summation of discharges, in cubic feet per second.
12. Net discharge, in cubic feet per second.

GENERAL SUMMATION.

	Cubic feet per second.
Escape between Horn Lake and Star Landing	13,000
Escape Commerce to Mhoon's	137,000
Escape to Mhoon's	150,000
Return flow, Mhoon's to McKinney Bayou	48,000
Net escape to McKinney Bayou	102,000
Escape between McKinney Bayou and Short Stop	38,000
Escape between Short Stop and Glendale	151,000
Net escape at Glendale	291,000
Escape Glendale to Friar's Point	158,000
Escape Friar's Point to Hughes	64,000
Net escape at Hughes	513,000
Escape at Gilchrist's	26,000
Net escape at Gilchrist's	539,000
Escape at Elleslie	7,000
Net escape into the Yazoo Bottoms	546,000

Widths of outlets.—The table of summation of the width of overflow is made for comparison with a similar table in Mr. J. B. Johnson's report on the Yazoo Front for the flood of 1882.

The increase in the width of the overflow taking place over the levee is due to the fact that the examination of this year was made at a stage as near the maximum as was practicable, while the observation stage of the flood of 1882 was about 1 foot below the maximum, and there was a consequent omission of considerable portions that were submerged at the higher stage.

The smaller distance given by the summation of the widths of crevasses is due to the closure of the breaks, and the permanence of the line in the second levee district.

Table of widths of overflow, Yazoo Front, 1883.

Locality.	Movement of overflow.	Kind of outlet.			Total submergence.	
		Over bank.	Over levee.	Through crevasses.	Feet.	Miles.
		Feet.	*Feet*	*Feet.*		
Horn Lake to Mhoon's	Escape	9,700	3,500	8,700	21,900	4.1
Mhoon's to McKinney Bayou	Return flow		13,800	1,400	15,200	2.9
McKinney Bayou to Glendale	Escape	800	11,500	9,200	21,500	4.0
Glendale to Friar's Point	Escape			3,500	3,500	0.7
Friar's Point to Hughes	Escape		1,700	3,600	5,200	1.0
Sunflower Landing	Stationary	10,500			10,500	2.0
Gilchrist and Elleslie	Escape			800	800	0.2
Total		21,000	30,500	27,200	78,700	14.9
Total in miles		4	5.8	5.1	14.9	

Table of water escape of the flood of 1883 over that portion of the left bank of the Mississippi River forming the front of the Yazoo Bottoms from Bull's Head to the mouth of the Yazoo River.

[ABBREVIATIONS: V, surface velocity, in feet per second. W, width in feet of the cross-section to which V and D are applied. D, mean depth of the cross-section, in feet. C, coefficient of reduction. A, direction of flow; inflow refers to the water flowing into the Yazoo Bottoms from the Mississippi River; outflow refers to the water returning to the river. O, observation stage referred to the maximum stage of 1883. O′, observation stage referred to the maximum stage of 1882. Q, escape from the river, in cubic feet per second; with minus sign it indicates return flow. Q″, net escape, in cubic feet per second.

Date.	Locality.	Outlet.	V	W	D	C	O	O′	A	Q	Q
1883.											
Mar. 7	Horn Lake Levee	Two crevasses	3.0	270	3.0	.7			Inflow	1,700	
7	Norfolk Landing						—.2	—.75	do		
7	Harklerode's	Crevasse	4.0	150	4.0	.7			do	400	
7	From Harklerode's to Star Landing	Over bank	1.0	5,000	1.5	.65			do	4,900	
7	do	do	0.7	3,500	2.5	.65			do	4,000	
7	do	do	1.5	1,200	1.5	.7			do	1,900	
											12,900
7	From 2½ miles below Commerce to Mhoon's Landing.	Over levee	2.0	600	0.5	.7			do	400	
7	do	Crevasse	3.0	100	10.0	.7			do	2,100	
7	do	do	3.0	30	4.0	.7			do	300	
7	do	do	3.2	120	5.0	.7			do	1,300	
7	do	do	3.5	125	4.0	.7			do	1,200	
7	do	do	3.5	40	3.0	.7			do	300	
7	do	do	3.3	250	5.0	.7			do	2,900	
7	do	do	3.1	250	5.0	.7			do	2,700	
7	do	do	3.0	410	5.5	.7			do	4,700	
7	do	do	2.3	40	5.0	.7			do	300	
7	do	do	2.0	100	4.0	.7			do	600	
7	do	do	2.0	195	3.0	.7			do	800	
7	do	do	3.6	50	7.0	.7			do	900	
7	do	Over levee	2.0	330	0.5	.7			do	200	
7	do	Crevasse	4.6	130	6.0	.7			do	2,500	
7	do	Over levee	4.0	1,640	0.5	.7			do	2,300	
7	do	Crevasse	4.3	100	5.0	.7			do	1,500	
7	do	do	5.0	80	4.5	.7			do	1,300	
7	do	do	4.0	66	6.0	.7			do	1,100	
7	do	do	4.5	200	6.0	.7			do	3,800	
7	do	Over levee	3.4	410	0.3	.7			do	300	
7	do	Crevasse	3.0	55	6.5	.7			do	800	
7	do	do	3.8	30	14.0	.7			do	1,100	
7	do	do	4.2	30	12.0	.7			do	1,100	
7	do	do	4.0	630	4.0	.7			do	7,100	
7	do	do	3.8	170	6.0	.7			do	2,700	
7	do	Three crevasses	3.5	250	6.0	.7			do	3,700	
7	do	Crevasse	3.3	30	7.0	.7			do	500	
7	do	do	4.0	130	6.0	.7			do	2,200	

7	......do	......do	4.0	180	5.5	.7	....	....	...do	2,800	
7	......do	......do	3.7	65	6.0	.7	....	....	...do	1,000	
7	......do	......do	4.0	15	6.0	.7	....	....	...do	800	
7	......do	......do	4.7	80	6.5	.7	....	....	...do	1,700	
7	......do	......do	4.7	105	5.0	.7	....	....	...do	2,700	
7	......do	......do	4.2	460	7.0	.7	....	....	...do	9,500	
7	......do	......do	4.7	145	7.5	.7	....	....	...do	3,600	
7	......do	......do	5.0	40	7.0	.7	....	....	...do	1,000	
7	......do	......do	5.0	25	8.0	.7	....	....	...do	700	
7	......do	......do	3.2	460	5.0	.7	....	....	...do	5,200	
7	......do	......do	2.8	245	6.5	.7	....	....	...do	3,100	
7	......do	......do	2.7	30	6.0	.7	....	....	...do	800	
7	Mhoon's Landing	......do	4.8	880	7.0	.7	±.00	—.60	...do	20,700	
7	Vicinity of Mhoon's Landing	......do	4.2	1,250	6.0	.7	....	....	...do	22,000	
7	......do	......do	4.0	430	7.0	.7	....	....	...do	8,400	
8	......do	......do	5.1	235	3.5	.7	....	....	...do	2,900	
8	......do	Over levee	2.0	480	0.5	.7	....	....	...do	800	149,800
8	From 1 mile below Mhoon's Landing to McKinney Bayou.	......do	3.0	230	0.5	.7	....	....	Outflow	— 2,400	
8	......do	......do	3.5	720	0.5	.7	....	....	...do	— 900	
8	......do	......do	3.0	7,500	1.0	.7	....	....	...do	—15,800	
8	......do	Crevasse	4.3	660	2.5	.7	....	....	...do	— 5,000	
8	......do	Over levee	2.0	1,950	2.0	.7	....	....	...do	— 5,500	
8	......do	......do	2.7	670	0.3	.7	....	....	...do	— 400	
8	......do	Crevasse	3.7	130	3.0	.7	....	....	...do	— 1,000	
8	......do	Over levee	3.0	410	1.0	.7	....	....	...do	— 900	
8	......do	Crevasse	4.0	295	3.0	.7	....	....	...do	— 2,500	
8	......do	Over levee	3.0	2,300	0.8	.7	....	....	...do	— 3,900	
8	McKinney Bayou	Bayou	2.7	330	15.0	.7	....	....	...do	— 9,400	102,100
8	McKinney Bayou to Austin	Over levee	2.1	30	2.0	.7	....	....	Inflow	100	
8	......do	......do	2.0	1,070	1.5	.7	....	....	...do	2,200	
8	......do	......do	2.0	2,000	1.0	.7	±.00	—.35	...do	2,800	
8	......do	Crevasse	2.0	360	15.0	.7	....	....	...do	7,600	
8	......do	......do	2.0	120	12.5	.7	....	....	...do	2,100	
8	At Austin	......do	3.1	260	15.0	.7	....	....	...do	8,500	
8	From Austin to Short Stop	......do	3.1	100	8.0	.7	....	....	...do	1,700	
8	......do	......do	3.4	80	5.0	.7	....	....	...do	1,000	
8	......do	Over levee	2.0	410	0.5	.7	....	....	...do	300	
8	......do	Crevasse	2.8	130	30.0	.7	....	....	...do	7,600	
9	Short Stop to Sunflower Lake	......do	3.5	200	8.5	.7	....	....	...do	4,200	
9											140,200
9	At Ridge	......do	1.0	80	3.0	.7	....	....	Outflow	—200	140,000
9	......do	......do	3.9	20	6.0	.7	....	....	Inflow	300	
9	......do	......do	4.0	90	7.0	.7	....	....	...do	1,800	
9	......do	......do	4.0	115	7.0	.7	....	....	...do	2,300	
9	......do	......do	4.0	80	6.5	.7	....	....	...do	1,500	
9	......do	......do	4.7	30	8.0	.7	....	....	...do	800	
9	......do	......do	5.0	30	7.0	.7	....	....	...do	700	
9	Back of Sunflower Lake	Three crevasses	2.0	995	35.0	.7	....	....	...do	48,800	

Table of water escape of the flood of 1883, &c.—Continued.

Date.	Locality.	Outlet.	V	W	D	C	O	O'	A	Q	Q''
1883. Mar. 9	Sunflower Lake to Trotter's	Crevasse	3.1	375	9.0	.7			Inflow	7,300	
9	do	do	2.4	85	13.0	.7			do	1,900	
9	do	do	1.2	1,640	3.3	.7			do	4,500	
9	do	do	2.2	130	9.0	.7			do	1,800	
9	do	do	2.0	80	6.0	.7			do	700	
9	do	do	2.0	115	13.0	.7			do	2,100	
9	do	Over levee	2.2	1,150	1.5	.7			do	2,700	
9	do	Crevasse	4.2	235	6.0	.7			do	4,100	
9	do	Over levee	2.0	655	1.0	.7			do	900	
9	do	Two crevasses	3.0	440	10.0	.7			do	9,200	
9	do	Over levee	1.0	1,150	1.0	.7			do	800	
9	do	Crevasse	5.1	330	5.5	.7			do	6,500	
9	do	do	3.0	655	2.5	.7			do	3,400	
9	do	do	3.2	330	2.0	.7			do	1,500	
9	do	do	1.0	165	15.0	.7			do	1,700	
9	do	Over levee	1.0	655	1.5	.7			do	700	
9	do	Crevasse	2.3	345	3.0	.7			do	1,700	
9	do	do	0.8	165	30.0	.7			do	2,800	
9	do	Over levee	1.0	655	1.5	.7			do	700	
9	do	Crevasse	4.0	195	4.0	.7			do	2,200	
9	do	Over levee	3.5	2,500	2.5	.7			do	15,300	
9	Trotter's field	Levee caved	3.0	800	4.5	.7			do	7,600	
9	From Trotter's to Glendale	Over levee	1.0	2,000	0.5	.7			do	700	
9	do	Crevasse	4.0	30	4.0	.7			do	300	
9	do	do	4.0	50	5.0	.7			do	700	
9	do	do	3.7	175	4.0	.7			do	1,600	
10	do	do	2.7	270	24.5	.7	—.05	—.85	do	12,500	
											291,300
10	Glendale	do	6.3	564	10.5	.7			do	26,100	
10	From Glendale to Friars Point	do	7.0	215	26.0	.7			do	27,400	
10	T. C. Ferguson's (broke March 5, 1883)	do	6.5	525	26.0	.7			do	62,100	
10	do	do	7.0	210	10.5	.7	.05	—.47	do	10,800	
10	do	do	2.0	475	10.0	.7			do	6,600	
10	do	do	1.7	130	9.5	.7			do	1,500	
10	do	do	1.5	810	10.5	.7			do	8,400	
10	do	do	3.0	310	9.0	.7			do	5,600	
10	1 mile above Friars Point (broke March 5, 1883)	do	3.4	780	8.0	.7			do	14,900	
											449,700
11	From Friars Point to Island No. 63	do	5.0	165	11.0	.7			do		
11	do	do	2.4	885	7.5	.7			do		
11	do	do	2.0	270	9.5	.7			do	24,400	
11	do	do	2.0	270	10.0	.7			do		
11	do	do	4.0	270	8.5	.7			do		
11	do	Over levee	2.0	65	6.3	.7			do		

11	......do	......do	2.0	165	0.5	.7	....	....	....do	100	
11	...... do	......do	2.0	100	1.0	.7	....	....	....do	100	
11	..... do	Crevasse	4.0	110	3.0	.7	....	....	....do	1,000	
11	..... do	Over levee	2.0	330	0.8	.7	....	....	....do	100	
11	......do	......do	2.0	330	0.5	.7	....	....	....do	200	
11	......do	Crevasse	3.0	890	2.0	.7	....	....	....do	1,600	
11	......do	......do	3.4	210	14.0	.7	....	....	....do	7,000	
11	......do	Over levee	2.0	330	0.5	.7	....	....	....do	200	
11	......do	Crevasse	5.0	105	7.0	.7	....	....	....do	2,600	
11	......do	......do	5.3	135	7.0	.7	....	....	....do	3,500	
11	......do	Over levee	2.0	425	0.5	.7	....	....	....do	800	
11	......do	Crevasse	3.2	335	5.0	.7	....	....	....do	3,800	
11	......do	......do	3.2	195	11.0	.7	....	....	....do	4,800	
11	......do	......do	3.0	195	5.0	.7	....	....	....do	2,000	
11	......do	......do	4.0	185	13.0	.7	....	....	....do	6,700	
11	......do	......do	4.2	165	4.0	.7	....	....	....do	1,900	
11	Back of Island No. 63	......do	2.9	285	7.0	.7	....	....	....do	4,000	
											514,00
11	Gap in levee above Sunflower Landing (2 miles)	Levee caved	Slack	10,500	5.5	.7	±.00	+.16	Slack	....	
12	Gilchrist place, 3 miles below Australia	Crevasse	5.0	310	23.5	.7	−.33	−.30	Inflow	25,500	
											539,500
15	Ellesllie	......do	3.0	160	4.5	.7	−.05	−1.9	....do	1,500	
15	......do	......do	7.5	165	3.0	.7	....	....	....do	2,600	
15	......do	......do	8.0	155	3.0	.7	....	....	....do	2,600	
											546,200

Discharge of the Yazoo River, March 16, 1883—2 p. m.

Locality.	Number.	Partial areas, square feet.	Measured velocity, feet per second.	Mean velocity, feet per second.	Discharge, cubic feet per second.
Left bank	1	15,640	1.52	1.40	21,900
Do	2	18,690	1.54	1.42	26,500
Do	3	12,920	1.09	1.00	12,900
Right bank					
Total		47,250			61,300

Effective width of cross-section, 773 feet; area of cross-section, 47,250 square feet; mean depth, 61.1 feet; mean velocity, 1.3 feet per section; coefficient to reduce observed velocity to mean, .92; discharge, 61,300 cubic feet per second.

The discharge section was located 15 miles, approximately, above the mouth of the Yazoo River and just below the junction of Steele Bayou.

The base line was located on the left bank at E. Corwent's Plantation; the right bank was submerged 6 feet, and the left bank was exposed 6¼ feet.

The stage of the Yazoo was reported to be 8 feet, approximately, below the high water of 1882.

The velocity was measured by means of rod-floats immersed 15 feet, timed by an ordinary watch; locations were made with a transit; distances were measured with stadia.

TENSAS FRONT.

The Mississippi River front of the Tensas Bottom extends from Cypress Creek to Red River.

The examination of the flood was made only as far as Delta, La., for reasons before mentioned.

As the instructions stated explicitly that the work was to commence at Cypress Creek, no effort was made to obtain an estimate of the amount of water on the bottoms between the hills and the mouth of Cypress Creek, a distance of 5 miles in an air line. Such an estimate may be of importance, for although it is only in exceptional cases that the Mississippi River contributes, still there is a considerable inflow over this portion of the front tributary to the Tensas bottoms, and, were it protected against overflow, all of the water that now escapes would become tributary to the Mississippi.

RESULTS.

The overflow water in the Tensas Bottom for the portion examined was reported to be relatively higher than in 1882.

At Arkansas City the high water of 1883 was .7 foot lower than the high water of 1882, while the height of the water in the rear of the levee was .5 foot lower than in 1882. At Goodrich's the high water of 1882 was 2.5 feet higher than the high water of 1883, while the depth of the overflow on the plantation was, in 1882, only 1.5 feet greater than in 1883.

The estimates for the discharge of all outlets will be found in the tabulation, which gives the same details as are mentioned in the section on the Yazoo Front.

GENERAL SUMMATION.

	Cubic feet per second.
Flow into the river from Wilburn's to ——	3,000
Escape, to 2 miles below Chicot	44,000
Net escape, to 2 miles below Chicot	41,000
Return flow, from 2 miles below Chicot to the Gordon Place	48,000
Net flow into the river at Gordon's	7,000
Escape, Gordon's to Llewellyn's	84,000
Net escape at Llewellyn's	77,000
Return flow, Llewellyn's to Linwood	6,000
Net escape at Linwood	71,000
Escape at Luna	31,000
Escape at Whiskey Chute	3,000
Escape at Ashton	24,000
Escape at Goodrich's	59,000
Net escape at Goodrich's	188,000

Table of water escape of the flood of 1883 over that portion of the right bank of the Mississippi River, forming the front of the Tensas Bottoms, from the mouth of Cypress Creek to Delta, La.

[ABBREVIATIONS: V, surface velocity in feet, per second. W, width in feet of the cross-section to which V and D are applied. D, mean depth of the cross-section, in feet. C, coefficient of reduction. A, direction of flow; inflow refers to the water flowing into the Tensas Bottoms from the Mississippi River; outflow refers to the water returning to the river. O, observation stage referred to the maximum stage of 1883. O′, observation stage referred to the maximum stage of 1882. Q, escape from the river, in cubic feet per second; with minus sign it indicates return flow. Q″, net escape from the river in cubic feet per second.]

Date.	Locality.	Outlet.	V	W	D	C	O	O′	A	Q	Q″
1883.											
Mar. 12	From Wilburn's to Sappington's	Over levee	2.0	650	0.5	.7			Outflow	—500	
12	do	Crevasse	1.0	260	6.0	.7			do	—1,100	
12	do	do	1.0	260	0.5	.7			do	—100	
12	do	Over levee	1.0	320	0.5	.7			do	—100	
12	do	Crevasse	0.7	230	11.0	.7			do	—1,200	
12	do	Over levee	0.7	360	0.3	.7			do	—100	
											—3,100
12	do	Crevasse	Slack.	100	6.0				Slack		
12	do	Over levee	1.0	660	0.3	.7			Inflow	100	
12	do	Crevasse	2.0	50	4.5	.7			do	300	
12	do	do	2.0	85	10.0	.7			do	1,200	
12	do	do	2.2	660	2.5	.7			do	2,500	
12	From Sappington's to Chicot	do	2.2	195	7.5	.7			do	2,300	
12	do	do	2.0	980	2.0	.7			do	2,700	
12	do	do	2.0	490	25.0	.7			do	17,100	
12	do	Over levee	1.0	330	0.5	.7			do	100	
12	do	do	1.0	330	1.0	.7			do	200	
12	do	do	1.0	1,640	0.5	.7			do	600	
12	do	do	2.0	655	1.0	.7			do	900	
12	do	do	1.0	1,310	0.5	.7			do	500	
12	do	do	2.0	655	0.5	.7			do	500	
12	do	do	2.0	655	1.0	.7			do	900	
12	do	Crevasse	2.3	30	5.0	.7			do	200	
12	do	Over levee	2.3	490	1.0	.7			do	800	
12	do	do	2.0	330	0.3	.7			do	100	
12	From Chicot to Arkansas City	do	2.0	1,970	1.0	.7			do	2,800	
12	do	do	2.0	8,000	1.0	.7			do	11,200	
											40,900
12	do	do	2.0	10,000	1.0	.7			Outflow	—14,000	
13	Arkansas City	do	2.0	7,500	0.5	.7	—.05	—.80	do	—5,300	
13	From lower end of new levee to the Gordon place	do	2.0	20,000	1.0	.7			do	—28,000	
											—6,400
13	do	Two crevasses	2.0	60	4.0	.7			do	—300	
13	do	Over levee	1.0	655	0.3	.7			do	—100	
											—6,800
13	Two miles above Gaines's Landing	do	1.0	330	1.0	.7			Inflow	200	
13	do	do	2.0	1,640	0.5	.7			do	1,100	

Table of water escape of the flood of 1883, &c.—Continued.

Date.	Locality.	Outlet.	V	W	D	C	O	O'	A	Q	Q''
1883.											
Mar. 13	Just above Gaines's Landing	Crevasse	2.1	345	22.5	.7			Inflow	11,900	
13	do	Over levee	2.0	655	0.5	.7			do	500	
13	do	Crevasse	2.0	215	2.0	.7			do	600	
13	do	do	2.3	65	16.0	.7	—.06	—.46	do	1,700	
13	do	do	3.0	100	10.0	.7			do	2,100	
13	do	do	3.0	65	3.0	.7			do	300	
13	do	do	3.2	65	5.5	.7			do	800	
13	do	do	3.0	60	5.0	.7			do	600	
13	Gaines's Landing to Point Comfort	do	3.0	215	5.0	.7			do	2,600	
13	do	Seven crevasses	3.0	90	2.0	.7			do	400	
13	do	Crevasse	1.8	2,045	0.2	.7			do	16,000	
13	do	do	1.7	660	6.0	.7			do	4,700	
13	do	do	1.3	330	6.0	.7			do	1,600	
13	do	do	1.0	100	4.0	.7			do	300	
13	do	do	1.3	330	6.5	.7			do	2,000	
13	do	do	1.3	60	4.5	.7			do	300	
13	do	do	1.3	65	4.0	.7			do	200	
13	do	do	1.3	215	3.5	.7			do	700	
13	do	do	1.3	100	5.5				do	500	
13	do	do	2.0	60	5.0	.7			do	600	
13	do	do	1.3	295	5.0	.7			do	1,300	
13	do	do	1.3	330	5.0	.7			do	1,500	
13	do	do	1.3	305	5.0	.7			do	1,600	
13	do	do	1.3	410	6.0	.7			do	2,200	
13	do	do	1.7	2,600	5.4	.7			do	12,800	
13	do	do	1.7	820	7.0	.7			do	6,800	
13	do	do	2.0	835	4.0	.7			do	4,800	
13	do	do	2.5	200	5.0	.7			do	1,700	
13	do	Levee washed	3.0	130	1.0	.7			do	300	
13	Back Linwood Place	Over levee	2.0	625	0.3	.7			do	200	
13	do	do	2.0	655	0.5	.7			do	500	77,000
13	Llewellyn's	Crevasse	1.0	15	2.0	.7	00	—.58	Outflow		
14	Front Linwood Place	Over levee	2.0	4,000	1.0	.7			do	—5,600	71,400
14	Above Luna	Crevasse	1.5	5,300	5.5	.7	00	—.58	Inflow	30,600	
14	Whisky Chute	Levee caved	3.1	330	4.5	.7			do	8,200	105,200
14	Ashton	Old crevasse	2.3	150	10.0	.8	00	—1.0	do	2,600	
14	do	do	2.8	150	7.0	.8			do	1,900	
14	do	do	2.0	3,000	3.0	.65			do	11,700	
14	do	do	1.0	11,500	1.0	.65			do	7,500	128,900

14	Wilson's Point						±00	—2.4			
15	Goodrich's	Crevasse	4.0	425	*12.0	.7			Inflow	14,300	
15	do	do	4.0	165	*11.5	.7			do	5,400	
16	do	do	4.1	990	*11.0	.7			do	31,300	
16	do	Between new and old levees	2.3	†800	6.0	.7	±00	—2.5	do	7,700	187,600
16	Goodrich's (check estimate)	Gap in line of new levee	2.0	†9,400	4.5	.7			do	59,200	

* Depth in the rear of the locus of scour; approximately equal to one-third of the mean depth of the section in the line of the levee.

† Effective width.

5.—YAZOO, TENSAS, AND ATCHAFALAYA BASINS, FLOOD OF 1884.

(By John Ewens, United States Assistant Engineer.)

UNITED STATES STEAMER PATROL,
August 9, 1884.

SIR: I have the honor to submit herewith my report of the investigation of the flood escape into the Yazoo and Tensas Basins during high water of 1884; also, discharge measurements made on the Mississippi River at various points, on the Saint Francis and Yazoo Rivers, and in Bayou La Fourche, together with tables showing maximum stages of the river at various points, and also miscellaneous crevasse measurements made from Memphis to New Orleans. All done in accordance with your instructions of February 28, 1884.

Very respectfully, your obedient servant,

JOHN EWENS,
United States Assistant Engineer.

First Lieut. SMITH S. LEACH,
Corps of Engineers, U. S. Army,
Secretary Mississippi River Commission.

REPORT.

I received instructions by express at Memphis, Tenn., on the evening of February 27, 1884. Preparations were immediately made, and party left the morning of the 28th, at 10 o'clock. An earlier start would have been made were it not for the freezing cold and stormy condition of the weather. My instructions were to determine the water escape into the Yazoo Basin from Horn Lake to Helena, and to pay no attention to the Saint Francis side. I was to visit all crevasses, new or old, in the Yazoo Front as far as Cypress Creek; to ascertain the amount of water going through the levee from Amos Ridge down to the Mississippi below Sunflower, on the Yazoo side. Reported crevasses only were to be visited. The flow into Tensas from Cypress Creek to Ashton was to be determined; below Ashton, on the Tensas side, reported crevasses only were to be visited in addition to the above. The discharge of the Mississippi was to be measured at Hays' Landing, Mississippi. The discharge of the Saint Francis and theYazoo Rivers was also to be taken. On arriving at Vicksburg, after completing the work noted above, instructions were received from you by telegraph to continue the crevasse discharge measurements and flood work down to New Orleans, which was done.

Party.—The work was accomplished by my regular engineering party, which is composed solely of the regular crew of the United States steamer Patrol. The steamer was used in every case where practicable, but, on account of the levees being situated back from the river front, skiffs had to be employed nearly exclusively.

In general, where skiffs can be used on river work they are far superior to any other conveyance for rapid work, which, in turn, means economy not only of time but fuel as well.

Method.—As has been stated above, the general location of the levees made it necessary to do the work with skiffs the great part of the distance traversed. As the outlets were principally through the levees, I found it necessary to follow them incessantly in order to secure complete measurements of the flood-escape through them. In many cases I found the levee over 6 miles back from the river bank. This was the case particularly in bends where, for economy in building, they were run across the necks or peninsulas at these points. The plan of working was as follows: The work of each day was so arranged that the steamer could be sent ahead to some landing that the field party in all probability would make the same night; this arrangement reduced the fuel expense about half, and retarded the wear of the machinery to a considerable extent. The work on each outlet consisted of a preliminary examination, which included the nature of the outlet, its cause, its present and probable future effect. The discharge in number of cubic feet of water passing through the break was then determined. The details of this work were as follows:

1. The section width of the outlet was determined. In cases where the section width was quite great, the measurements were made with a stadia rod. In cases where the section width was, say, between 50 and 125 feet, the measurements were made with the sounding line, which was a very quick yet accurate way of securing it.

2. A transverse section across the outlet was next sounded. These soundings were taken with a three-eighths inch cotton line graduated to feet, and having a 15-pound lead attached. In taking the soundings the boat was kept on a line between the ends of the levee, or points limiting the cross-section. Where the current was too swift to

hold up against it the soundings were taken by running up above the section and then drifting back over the section. A sufficient number of soundings were taken to give a quite well defined contour of the bed of the outlet.

3. The surface velocity was then taken at as many points of the section as possible. As it was impossible to employ floats, a device known as ship's log was used in taking the velocity observations. This device is made of wood, and consists of a quarter segment of a circle having a diameter of about 12 inches, and a surface thickness of 1 inch. The curved edge of this segment is covered with a thin sheet of lead sufficient to give it a vertical position when in the water. This log is attached to a fine seagrass line by three fine wires. Two of the wires are detachable. This connection at the apex is made permanent, so as to draw in the log when the observation is completed. The two detachable strings that connect the log with the reel line terminate in two corks, which fit into two holes in the extremities of the curved and weighted part of the log. When the observation is complete, a slight twitch of the line pulls out these corks; the log by this means is easily drawn in, as it is in this condition nothing more than a small piece of thin board floating on the water surface. The grass line to which the log is attached is rolled in on an ordinary fishing reel, that has a small brake or clutch attachment for arresting the progress of the line at any desired point. The line is graduated into feet; every tenth foot is marked by pieces of line of color different from that of the line, and from each other. A stop-watch measuring one-fifth of a second was used in taking the time. The point of section where the velocity was to be determined having been selected, the skiff was held, either by anchoring or by holding upon the oars; the log was then launched and allowed a preliminary run of several feet, until it adjusted itself to the natural flow of the water; when time was called, the stop-watch was started, and the foot-mark or fractional division of the line that left the reel at same instant noted. When the line had nearly reached its limit on the reel, time was called again, the reel brake applied, and the watch stopped. These two quantities being determined, the surface velocity was deduced from them. In taking these observations care was taken to avoid the influence of eddies and boils, and a reach of the surface over which the velocity was visibly uniform was always sought after and used where possible. In addition to the above, the following points which are salient in crevasse investigation were determined:

1. Was the flow through a regular break or over the levee?

2. Was the flow free, or was it retarded by obstructions before reaching the section; were these obstructions in the bed of the section; was the bed of the section a natural one, or was it covered with a growth of young trees or underbrush?

3. Was the direction of the flow normal to, or at an angle with, section line?

4. Were there eddies or boils on a section line between center lines of the two ends of the levee, or limiting ends of the crevasse section? The presence or absence of these would indicate whether there were deep holes excavated below the bed proper of the section.

The necessity of strict attention to all these details must be obvious to any one familiar with crevasse work, and who knows how uncertain the most refined field measurements may be from a hydraulic standpoint when formulated. The selection of a certain stratum for velocity as described above may, to persons inexperienced in work of this character, seem unnecessary. Now, the uniform stratum of water referred to, and over which the velocity should be taken, is generally a middle section, whose length is about one-third the distance from the mouth of the outlet, out to where the crevasse influence is exerted on the river or body of water from which the water flows. I mean, that if this distance was 300 feet, the stratum would be 100 feet in length, and its commencement would be 100 feet from the mouth of the crevasse. In the Davis crevasse the influence of the draught of this break was manifest about 300 feet out into the river; the distance out at which the influence is felt varies with level of the land behind the crevasse, and the width of the crevasse itself. The lower the latter the greater will be the distance at which the draw affects the body of water which feeds the break.

Before closing the discussion on the velocity, it will be well here to say a word regarding the velocities at the upper and lower side of a crevasse section. In most instances this was found to be greater on the upstream end of the crevasse than on the lower side. A skiff could always be more easily *cordelled* or rowed up near the lower edge of the break, than on the upper side, which fact, to a certain extent, practically proves the assertion. I attribute this to the fact, that the water that flanks the river bank in the upper side of the crevasse has the effect of the draw of a much larger mass of moving water than the volume that flanks the lower side, *i. e.*, the mass of moving water that enters the break has a greater moving force. The result of this is the acceleration of the mass of water on the upper side. On the lower side the water that enters the break is affected by the volume that endeavors to continue down the main river; the resultant of these two forces causes the retardation referred to above, and in consequence of which we find a diminution of velocity at the lower end of the break. All the points hinted at above were carefully looked after in the work

of which this report treats; and although work of this character will always have a tinge of unreliability about it, yet when the details are zealously attended to in the field, and carefully followed in every particular, the supposed non-tangible qualities will become more tangible.

Calculation.—In calculating the discharge, the usual conventional method used in computing the discharge through a regular river section admitted of considerable modification. This was necessary, as the conditions are (practically) in every particular different. The ratio between the maximum surface velocity and the true mean velocity has as yet been but arbitrarily determined. Water, in passing through a crevasse, admits of every degree of change of velocity imaginable, and approximates to that of the velocity when flowing through a natural bed, only as the bed of the crevasse approximates to a natural bottom. Where deep holes are excavated in the heart of the break, the eddies and boils these holes generate upwards have, without doubt, a retarding effect on the velocity. We know from hydraulic experiments made at Lowell and other points, that water, when discharged through pipes of varying section, loses a large percentage of its velocity. The flow of water through a crevasse of constantly varying section can be reasonably compared to a semi-section of such a pipe, and the retardation can reasonably be assumed to be one-half also, *i. e.*, in that ratio. From this I have concluded that the coefficient used in the computation of work of this character in the past has been too small. I think a coefficient of 0.86 will, from the knowledge attainable at present on the subject, be approximately correct, or at least reasonably so.

In using the coefficient no distinction was made for cases where the discharge was over the bank, *i. e.*, if the section was taken near the edge, as in such cases the conditions would be analogous to the one discussed above; as the stratum of water beneath the bank surface in impinging against the banks produces retarding elements in the shape of vertical eddies and boils, just the same as when the flow is through a regular crevasse; this was visibly the case at all points of this character I examined.

The cross section, like the velocity, is, in the case of a crevasse, a very uncertain, if not altogether a variable quantity. In my work I endeavored to eliminate errors in sectional area, by taking sections that would approximate to a regular river section as closely as possible. In crevasses where deep holes were scoured out between the ends of the levee, and below the normal bed surface, I generally took a section immediately above or below the limiting ends of the outlet. In a majority of cases the levees are situated a number of miles back from the river, and run through dense woods. In these cases the sectional area is diminished to a very appreciable extent by obstructions of brush, young trees, &c. The co-efficient to be used in reducing the observed to the effective area must be a very variable quantity, and one that must be determined wholly by actual observation at the time the soundings are taken and section width determined.

The coefficient used in the computation of areas for this work varied from 10 to 60 per cent. A very close estimate was arrived at by simply noting the diameter of the brush and other obstructing material, and its density as a whole.

Tabulation.—In the tabulation found on the succeeding pages the arrangements were made so as to make them simple for immediate comparison. The tables contain—

1. Place or vicinity of break.
2. Date of examination.
3. Date on which outlet was opened.
4. Nature of outlet.
5. Direction of escape.
6. Stage of water with reference to its maximum.
7. Width of outlet in feet.
8. Area of outlet in square feet.
9. Reduced mean velocity in feet per second.
10. Discharge in cubic feet per second.
11. General remarks.

The summation of results is arranged as follows:

1. Name of swamp basin.
2. Reach of outlet.
3. Distance in miles.
4. Total section width.
5. Total section area.
6. Total discharge.

Following this is a table of high-water stage at the principal points on the Mississippi River during the three last great floods. I give these, as they will be of great interest in connection with other data contained in this report.

The last tabulation is one of discharges taken on the Mississippi at various points, and on the Saint Francis and Yazoo rivers, and on Bayou La Fourche.

Summary of work and travel.

Left—	Date.	Time.	Arrived—	Date.	Time.	Distance.
						Miles.
Memphis, Tenn	Feb. 28	10 a. m.	Vicksburg, Miss	Mar. 18	1.25 p. m.	369.3
Vicksburg, Miss	Mar. 19	2.30 p. m.	Davis Crevasse	Mar. 27	8 a. m.	353

Crevasses examined.—On Yazoo Front, 116; on Tensas Front, 48.

Discharges taken.—Mississippi River, at Hays' Landing, Miss.; Mississippi River, at Red River Landing, Louisiana; Mississippi River, at Carrollton, La.; Saint Francis River, at Westbrook, Ark.; Yazoo River, near Chickasaw Bayou; Bayou La Fourche, near Thibodeaux, La.

Description of the flood on the Yazoo Front.—The Yazoo Front proper is situated on the left bank of the Mississippi River, and extends from Memphis, Tenn., to Vicksburg, Miss. The portion examined in particular was that included between Horn Lake and Glendale, Miss. The discharge over this front into the Yazoo swamp was principally through breaks in the levee. The first crevasse found was on Horn Lake. From the latter point to Star Landing the water was over the bank at various points, but there was no perceptible discharge into the swamp. About half a mile above Star Landing there were two depressions in the ground through which the river was discharging an inappreciable volume of water into the swamp. Below this landing I found an old slough bottom which heretofore has been shut off from the river by a levee, which, though flooded, was currentless. From Star Landing to a point about one mile below Mhoon's, Miss., I found a series of nearly 70 regular outlets formed by breaks in the levee, and through which the river was discharging large volumes of water into the swamp. The width of these breaks varied from 5 to 3,000 feet; the largest one was at Mhoon's Landing. The dense timber land that intervenes between the river and the level above Mhoon's reduces greatly the discharge the river would make into the basin in this reach. The outlets on the reach just described were, in a majority of cases, caused first by the water running over the levee at points of low grade, this continued washing finally causing a large crevasse. In general, the crevasses on this reach can be considered due wholly to the negligence of the parties whom the levees protect, as the breaks could never have occurred by the simple pressure of the water against the levee. The points of low grade referred to above are places where the traffic across the levee has been concentrated. In many places great holes were caused by hauling logs across the levee.

From the crevasse one mile below Mhoon's to a point 2¼ miles above Austin, the direction of the flow is reversed; the water from the swamp was found to be returning to the river. The discharge, in a majority of cases, was by the water running over the top of the levee. About twelve regular breaks were found on this reach, the largest of which was McKinney Bayou, situated about two and one-half miles above the town of Austin. This bayou was leveed, but broke in 1882. Its width at date of examination was 321 feet; the maximum depth of water found in it was 27 feet. Before it broke, the levee had a culvert in it for carrying the swamp water back into the river. About 4 miles below Mhoon's, the levee described above connects with a high ridge of ground which attains its maximum elevation on the widow Saunders's place. This ridge forms a levee for about 2 miles, when (the ground becoming low) it connects again with the levee. From McKinney Bayou down, the direction of the flow changes again, the river discharging into the swamp. From Austin to O. K. Landing five outlets were found, the largest of which were the first one below the court-house at Austin, and the one at Denmark. From O. K. Landing down to the junction of Flower Lake and Neil's Bayou, sixteen crevasses were found; the largest of these outlets were found on the shore of Flower Lake. The largest one of the whole series was at the lower end of the lake; its width was 853 feet, its maximum depth 55.5 feet. The discharge through the breaks in Flower lake was very great, a fact I think due to the great reservoir pressure the lake exerts against the levee. From the lower end of Flower Lake to Trotter's, nine outlets were examined, the largest of which was the immense break at Trotter's, where the levee has caved into the river. From Trotter's to Glendale, opposite Helena, the point which limits the special examination of the Yazoo Front, the crevasses found were located along Eagle Lake, the largest being at Ferguson's gin-house. The water was also running over the levee at many places. From Glendale to Friar's Point the crevasses, though smaller in number, are very large and more destructive. The first crevasses met with after leaving Glendale, are the two on the Thompson place; then come the three Rozeil breaks near Delta, and then the Fant break. From Friar's Point to Hulberton a series of seventeen outlets were visited, twelve of which were what is known as the Garth break, and five of which compose what is termed the McLeod break. The lat-

ter breaks are near the head of Island No. 63. From Hulberton to Sunflower Landing the only outlet is what is termed the "Lewis Swamp." The river boundary of this swamp begins at Hushpuckana Creek and extends up the river a distance of over 5 miles. No perceptible discharge could be detected in this front. The flow was outward from Hushpuckana Creek on date of examination, March 10. From Sunflower to Prentiss the Hughes break in Vermillion Lake was the only one found. This break occurred early on the morning of February 29; it was caused, it is said, by a craw-fish hole. The crevasse was 768 feet wide; the water discharged through it passes down Clear Creek, and from thence into Bogue Phalia, the latter a very deep stream. From Prentiss to Vicksburg no crevasses were reported. There are, however, several small outlets from Chotard's to the mouth of the Yazoo, but nothing s-rious. From Hays' Landing to the mouth of the Yazoo River, what escape exists, flows from the river into the Yazoo Basin. During the great flood of 1882, the flow over this portion of the Yazoo front was reversed, the swamp water returning to the river.

Description of the flood on the right bank, from Helena to the mouth of Cypress Creek.—On the reach from Helena to Cypress Creek no discharge into the swamp was found. On the contrary, the swamp water was coming into the river at many points from Modoc, Arkansas, down to Cypress Creek; the flow is greatest on the reach from Ludlow's down. This swamp discharge comes principally from the White River Basin, which runs parallel to, and only a short distance from the Mississippi River along the reach referred to. It seemed to be more marked in the vicinity of Island No. 66, than at any other place.

Flood on the Tensas Front, general description.—The portion of this front that is bounded by the Mississippi River, is situated on the right bank, and begins properly at the point where Amos Ridge joins the great Opossum Fork levee, and extends down to the right bank of Shreve's Old River, just above Red River Landing. Amos Ridge is a high neck of land that borders the lower side of Amos Bayou. The point where it intersects the Opossum Fork levee, which point limits the overflow into Tensas Basin, is situated about 6 miles from the Mississippi River, and is about 3 miles from the point where Cypress Creek, Red Fork Bayou, and Boggy Bayou all come together. Cypress Creek, after leaving the Mississippi River, runs in a direction nearly parallel to it for a distance of nearly 5 miles; it then turns rather abruptly and runs nearly at right angles for a distance of about one-half mile, when it changes its course rather sharply again, and runs with and nearly parallel to Red Fork Bayou. The latter empties into Cypress Creek at the first of the sharp turns referred to. At the point where Cypress Creek makes the second sharp turn and runs nearly parallel to Red Fork Bayou, Boggy Bayou begins, and runs south until it joins Amos Bayou. The flood water that feeds the breaks along this levee comes principally from the Arkansas River. The stage of water in this district reached its maximum before the Mississippi had attained its extreme height. The water, after passing through the breaks in the levee from Amos Ridge down to the Mississippi, flows over the Tensas swamp lands. A large portion gets into the Tensas Basin direct through Bayou Maçon and other contiguous outlets, while a considerable volume reaches the Mississippi again via Boggy Bayou, near Island No. 80. From Arkansas City up to the Opossum Fork levee on Cypress Creek, the levee is nothing more than the old bed of the Little Rock, Mississippi River and Texas Railroad.

From Amos Ridge to the mouth of Cypress Creek this escape is principally through the large breaks in the levee. From the mouth of Cypress Creek to Arkansas City the escape is principally over the top of the levee, there being but few breaks of any magnitude. From Amos Ridge to a point about one mile below Chicot City, the discharge was into the swamp. From the latter point to Boggy Bayou, just below Arkansas City, the direction of the flow was reversed by the swamp water returning to the Mississippi River. From Boggy Bayou to Sterling the direction of the escape again changes; over this reach the river was discharging into the swamps. From Sterling to Ashton the change of flow occurs again, the swamp water returning to the river through about twelve large breaks in the levee, the largest of which is just below Gray's store. From Ashton to the mouth of Old River five outlets were found. These were at Hardscrabble, Bougère to Union Point, Black Hawk to Point Breeze, Point Breeze to mouth of Old River. The escape through all these outlets was over the bank proper, the levees having caved into the river. The water discharged through the Hardscrabble break passes directly into Lake Saint Joseph, and from thence by numerous lakes and bayous into the Tensas Basin. The water discharged through the remaining breaks, down to a point about one mile above Point Breeze, passes into Red River basin. From the latter point to Red River Landing, the direction of the discharge is changed. The swamp, or Red River water, over this reach was found emptying into the Mississippi. The discharge was outward from Old River on date of examination (March 21, 1884). I was informed that the change of flow in Old River and across the peninsula referred to took place on March 12, 1884. Previous to that date the Mississippi was discharging into the swamp over the reach referred to, and through Old River also.

DESCRIPTION OF FLOOD ON RIGHT BANK FROM RED RIVER LANDING TO NEW ORLEANS.

The first crevasse below Red River Landing was the one on the Batchelor place; this break was a very small one and did little or no damage. The next was the Morganza, discharging directly into Grand River, and from thence into the Atchafalaya swamp. It floods a portion of Point Coupee, Iberville, West Baton Rouge, and Saint Landry Parishes. This break occurred on the evening of March 14. The first intimation the levee watchers had of the break was the sudden appearance of a stream of water spouting up from one of the borrow pits on the inside and about seventy feet from the base of the levee. This stream of water kept growing larger until it reached the base of the levee, when all at once the levee proper at this point gave way. The break occurred at a point where it was least expected, and at what was supposed to be the safest part of the levee. The levee, before the break occurred, was a picture of strength; it was perfectly dry and stood from five to six feet above the water surface. The cause assigned for the crevasse was a deep bed of quicksand that existed below the muck ditch, and which connected with the bed of the river. This crevasse raised the flood surface in Bayou Plaquemine materially. The next crevasse met with was at Waterloo, seven miles below Bayou Sara, and occurred on the evening of March 23. The main levee at this point is some distance back from the river, but there is a protection levee on the river front. The latter gave way and precipitated a volume of water against the levee proper sufficient to break it. The levee on the river front served as a dike commanding the upper mouth of False River, was built in 1850, was 25 feet high, and had a very broad base. The breaks were due to an imperfectly constructed rice flume in the levee. This break is very apt to cause breaks in the protection levee at Grosse Tête, and thus overflow that valuable country. The water discharged through this crevasse takes the same course as the water discharged through the Scott levee took in 1882; it will affect the river front and all the places on the Chenille. The succeeding outlet was found on the Belle Air sugar plantation, 5 miles above Baton Rouge. This crevasse occurred on the morning of March 18. The cause of this break was attributed to a crawfish hole in the levee. All the fine sugar places in the immediate vicinity were under water from this break. This crevasse affects about the same parishes that Morganza does.

The next crevasses examined were those on the Guidry place, nearly opposite Convent, La. These breaks happened on the night of March 25, and were caused by the bursting of a rice flume built in the levee. The last crevasse on this bank of the river was the great Davis crevasse, situated at the railroad station of same name, in the Parish of Saint Charles, and about 21 miles from New Orleans. It occurred on March 15, and was caused by the levee giving away at a point where an old rice flume had been removed a few months previous to the high water. When the flume was taken out, the place left was filled in with fresh dirt, and not protected. The residents in the vicinity attribute the break to a muskrat hole. These animals were very numerous in the vicinity, and it is a well-known fact that they seek haunts formed of earth that has been displaced and transported from one place to another. The water discharged through this crevasse passes directly into numerous lakes and small bayous, and from thence into the Gulf. This crevasse floods completely the parishes of Saint Charles and Jefferson. It floods also the Vacherie settlement in Saint James Parish, and it backs the water up to a dangerous height in the rear of Algiers. It also backs up the crevasse water that comes through breaks on the La Fourche, and thus raises the flood height of water inside of the levee on the La Fourche.

Levees.—The location and course of the levee system along the river has been so fully described in previous reports of surveys, &c., that a description of them in this regard is unnecessary here. But a brief description of their condition at prominent points, with a few facts regarding their failure at many places during the high water of this year, will, I think, be of interest if not of importance here. With the exception of a few points where the levee was close to the bank and had caved off, I found the most disastrous crevasses were situated at considerable distances back from the river, and had dense woods intervening between them and the Mississippi, which protect them from the wash of the waves and materially from water pressure against their fronts. They had also a dense growth of Bermuda sod on them, in front and back of them. It will be seen from this that where the most crevasses were there was a larger number of safety factors. If levees failed with these natural protective adjuncts, it would be useless to build them. The cause of the breaks can be attributed simply to the abandonment and neglect of the levees by those whom they protect.

Beginning at Commerce, we find a levee protected nearly to Mhoon's by a dense woods on the river front. The breaks in this levee were all artifical ones, *i. e.*, they occurred at points where the levee had been worn by hauling logs, &c., across it, and by depredations of stock. As the river rose, incipient breaks, that a shovelful of dirt applied at the proper time would have obliterated, developed with the rise of the water into formidable crevasses.

From Mhoon's to Austin we find a similar state of affairs; the levee, from a protective view, is similarly situated to the one just described, but was a much finer one. The escape was principally over the top. The ground over which the levee runs is very high; at one point there is a stretch on a ridge of nearly 2 miles, where the ground itself is nearly above high-water mark. On the reach just mentioned, which is about 6 miles long, 2 feet of earth thrown up loosely would have protected the country from overflow the greater part of the way.

From Austin down to Flower Lake, the levee is a beautiful one; at flood stage it is nearly 3 feet above the water the greater part of the way, and has a dense thicket intervening between it and the river. The breaks were very small, and could have been easily repaired. From Flower Lake to Glendale, with the exception of the break at Trotter's, where the levee has caved into the river, the levee was in quite good condition, the breaks were not serious, and the place where the water was running over the top was not very deep. Along Flower Lake the levee was an unusually fine one, and was about 4 feet above the high-water mark. It will be seen from this that the crevasses from Horn Lake to Helena, which is the principal part of the Yazoo front, were not due to the pressure or ravages of flood water, but solely to simple neglect in caring for the levees during the low-water season. I speak particularly of this reach, as it is so often brought up to confront arguments in favor of levees, and to persons who are not familiar with the ground itself, and who know not the facts as they are.

The large number of breaks in this reach would furnish material for a very formidable argument against the utility and possible efficiency of levees in keeping out the waters of great floods. On the Tensas Front, from the mouth of Cypress Creek down, we find a quite similar state of affairs. Taking the reach from the creek to Arkansas City, we find a levee which is nothing more than an old railroad bed, over which the river is pouring, but a shallow depth of water, which a few feet of dirt on top would easily keep out. From Arkansas City to Gaines Landing, we find the levee is situated back in the timber, and is as well protected from the river as the levees previously referred to, yet we find breaks numerous, and from causes similar to those just mentioned. The effect floods have on levees protected by intervening woods having been discussed, a few words regarding levees situated on the immediate river front, and subject to all the forces the winds and water can generate is necessary to complete the discussion. The breaks between the mouth of Red River and New Orleans for this offered the best field of comparison, as they are nearly all on the river front.

On this reach we have a levee front of nearly 198.2 miles on both banks, which represent an aggregate of 396.4 miles. On this stretch we have six breaks that will not aggregate in length 3 miles. Three of these breaks were due wholly to defective rice flumes in the levees, two to the depredations of crawfish, and one, the Morganza, which was the only one that was not directly on the river, was said to have been caused by the action of a bed of quicksand beneath the base of the levee.

From this it will be seen that not one of the breaks on this vast stretch of river was caused by the action of the flood water direct, and all, with but one exception, were due simply to neglect before the flood, and lack of vigilance after the flood had arrived. People who have lived for years right at the Davis crevasse, which was the most disastrous one of the late flood, informed me that for several flood seasons, when the old rice flume was in the levee, they feared a break, but by watching it vigilantly they prevented it. Before the past flood arrived, the family who had been instrumental in preventing this crevasse during previous floods moved; the result was, the levee was not properly strengthened or guarded, and a disastrous crevasse was the fruit of this neglect. As a more conclusive proof that breaks or crevasses at flood stages of the river are due to lack of watchfulness and care, rather than to the ravages of the river itself, I could refer to the river front on the left bank from Baton Rouge down to New Orleans. This side of the river has been noted for its crevasses, among which was the great Bonnet Carré crevasse. The levees on this reach were looked after exclusively during the late high water by the Mississippi Valley Railroad Company, and although at times the situation at many points, especially at Bonnet Carré and the Angelina levee, looked critical, yet not a single crevasse occurred, simply because the levees were well protected and vigilantly watched. The experience of the past year has demonstrated, I think, very conclusively that rice flumes are the great crevasse makers, and that they should be abolished. That they are employed in such an advanced age as this is a mystery, as a siphon would be more efficient and perfectly safe. These facts, which are actual, show, I think, to an approximate extent at least, that levees can be built that will sustain the greatest flood the Mississippi has carried thus far. I think, in the past, too much weight has been given to the effect the pressure of water has against the sides of a levee, and the delusion produced by witnessing a break has done much to strengthen this belief. This pressure, I think, with the exception of the cases of concave bends, furnishes no material for argument whatever. In bends the levees are generally run across the necks, so this obstacle is to a certain extent removed, From the brief description just given of actual facts

observed during the three greatest floods the Mississippi Valley has ever experienced, I feel partially competent to give a few crude points regarding what should be done to make the levee system a continued success. First, as to the type of levee. The old levees, built along in 1858 and 1859, furnish the best example, and should be patterned after where new levees are built, or old ones repaired in the future. In building the levee, borrow pits and ditches should be confined to the land side of the levee; where they are in front they furnish holes for crawfish, and where there is any current along the side of the levee they give rise to eddies and boils, which scour out great holes on the levee front, and these propagate a break. Where new levees are built, or when old ones are repaired, this work should be done immediately after the river falls, so as to give the new embankment time to settle before the flood water reaches it.

Where practicable, the growing of young trees, or hedge brush, should be encouraged on the front and near the base of the levee. After a levee is built, its care should be the next and all-important subject, as on it depends its usefulness and complete success. In the first place, traffic of all kinds should be prohibited, and the stock law rigidly enforced, especially in levee districts. At flood time the levee should be constantly watched, especially at points where danger is apprehended.

The flood season is usually at a time when plantation hands are not engaged; and they are so numerous compared with the miles of levees to be guarded that it would be easy to have the levees under complete surveillance continually during a flood. A levee never breaks spontaneously; it is always known several hours beforehand where danger is imminent by such signs as sipage water, the settling of the crown, &c.; and, by having sacks, lumber, and other defensive material properly distributed, an incipient break could be prevented from developing into a formidable crevasse in nine cases out of ten. From the calculations it will be seen that the net river discharge into the Yazoo and Tensas basins is considerably greater than the discharge of the Mississippi at Red River Landing. I take this point because it has no tributary influence below, and has no natural outlet until it reaches the Gulf, except the La Fourche, whose discharge is so small that it has little or no weight. The escape from the river into the swamps between the mouth of Red River and Carrolitou is more than half the actual flood discharge of the river at the latter point. These figures may at first seem startling, but when all the facts relative to them are considered wonderment will cease.

Before concluding, I can but say that I think a complete, efficient, and permanent levee system that will withstand the effects of the greatest flood the valley has ever been subjected to thus far is possible in every particular if the levees are properly built and protected, and properly guarded during the seasons of great floods. The latter factor is the principal one, and if carefully looked after will give the valley dry and fertile fields, and freedom from the distress and disaster which characterizes and always follows great floods.

Respectfully submitted.

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United States Assistant Engineer.

First Lieut. SMITH S. LEACH,
Corps of Engineers, U. S. Army,
Secretary Mississippi River Commission.

AUGUST 9, 1884.

Escape of the water of the Mississippi River into the swamps during the flood of 1884.

[These outlets began 5 miles above Mhoon's. There were dense woods on both sides of these outlets, so that the log line could not be used in a large number of instances.]

YAZOO BASIN FROM HORN LAKE TO HELENA.

Place.	Date of examination.	Date of opening of outlet.	Nature of outlet.	Direction of escape.	River below flood stage.	Width of outlet.	Area of outlet.	Reduced mean velocity per second.	Discharge through outlet per second.
					Feet.	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*
Horn Lake	Feb. 28, 1884	Mar. 5, 1882	Crevasse	Into swamp	0.2	170	2,650	2.50	6,625
5 miles above Mhoon's	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	10	10	1.72	17
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	10	10	1.72	17
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	5	5	1.72	17
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	125	1,340	2.66	3,572
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	35	77	2.58	198
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	100	260	1.97	514
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	110	260	2.58	670
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	260	1,120	2.58	2,889
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	6	12	2.58	30
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	200	660	2.58	1,702
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	350	1,330	2.58	3,431
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	25	75	2.58	193
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	15	20	2.58	51
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	25	50	2.58	129
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	35	87	2.58	225
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	18	36	2.58	93
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	36	108	2.58	279
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	60	180	2.58	464
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	50	150	2.58	387
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	10	30	1.72	51
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	15	30	2.58	77
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	50	100	2.44	244
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	560	1,960	2.58	5,056
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	50	150	2.58	382
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	100	550	2.15	1,182
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	50	200	1.72	344
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	110	385	2.58	993
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	15	45	1.72	77
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	75	225	2.58	580
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	250	925	2.58	2,386
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	800	3,200	2.15	6,880
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	200	1,140	2.58	2,941
Do	Feb. 29, 1884	Mar. 5, 1882	do	do	1.2	75	360	2.58	929
Do	Feb. 29, 1884	Feb. 29, 1884	Over levee	do	*1.2	3,000	4,490	1.72	7,720
At Mhoon's Landing	Mar. 1, 1884	Feb. 12, 1884	Crevasse	do	1.2	782	3,180	2.23	7,110

Do	Mar. 1, 1884	Feb. 12, 1882	...do	...do	1.2	47	112	3.01	339
Do	Mar. 1, 1884	Feb. 12, 1882	...do	...do	1.2	2,800	16,760	1.11	18,787
1 mile below Mhoon's	Mar. 1, 1884	Feb. 16, 1882	...do	Into river	1.2	200	600	2.15	1,290
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.2	1,500	4,500	2.58	11,610
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.2	1,500	4,500	2.58	11,610
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.2	850	5,660	1.89	10,708
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.1	20	124	2.15	258
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.2	40	80	2.15	172
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.2	15	60	3.44	206
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.2	6	12	1.72	20
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.2	18	45	3.44	154
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.2	14	28	1.72	48
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	1.2	{ 1,500	6,040	3.01	18,180
						{ 500	900	3.01	2,709
Do	Mar. 1, 1884	Feb. 16, 1882	Over levee	...do	0.65	1,800	1,800	3.44	5,192
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	0.65	125	125	3.44	430
Do	Mar. 1, 1884	Feb. 16, 1882	...do	...do	0.65	150	225	3.44	774
McKinney Bayou	Mar. 2, 1884	Feb. 16, 1882	Crevasse	...do	0.25	341	4,340	1.97	8,584
Do	Mar. 2, 1884		Over levee	Into swamp	† 0.65	11,560	23,120	2.15	49,708
At Austin	Mar. 3, 1884	Mar. 5, 1882	Crevasse	...do	0.15	{ 10,560	10,560	3.44	36,726
						{ 452	4,620	2.15	9,933
Below Austin	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	40	240	2.58	619
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	144	520	3.61	1,878
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	75	330	2.58	851
Do	Mar. 3, 1884	Mar. 5, 1882	Over levee	...do	0.15	600	1,500	2.15	3,225
Denmark	Mar. 3, 1884	Mar. 5, 1882	Crevasse	...do	0.15	196	4,840	2.92	14,152
O. K. Landing	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	‡ 25	37	2.15	80
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	196	940	3.01	2,829
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	30	135	3.01	406
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	38	171	3.01	514
Jones' store	Mar. 3, 1884	Mar. 5, 1882	...do	River from swamp	0.15	100	640	0.43	275
Do	Mar. 3, 1884	Mar. 5, 1882	...do	Into swamp	0.15	40	40	0.86	34
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	30	45	0.86	38
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	78	452	3.01	1,361
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	60	90	2.58	232
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	20	30	2.58	77
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	100	200	2.15	430
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	25	50	2.15	107
Flower Lake	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	60	162	4.30	696
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	853	33,000	1.89	62,436
Do	Mar. 3, 1884	Mar. 5, 1882	...do	...do	0.15	420	2,840	4.04	11,479
Do	Mar. 6, 1884	Mar. 5, 1882	...do	...do	0.0	105	980	3.69	3,624
Do	Mar. 6, 1884	Mar. 5, 1882	...do	...do	0.0	10	10	1.29	12
Do	Mar. 6, 1884	Mar. 5, 1882	Over levee	...do	0.0	800	3,240	2.58	8,359
Do	Mar. 6, 1884	Mar. 5, 1882	Crevasse	...do	0.0	600	1,020	2.58	2,631
Do	Mar. 6, 1884	Mar. 5, 1882	...do	...do	0.0	86	731	3.01	2,200
Do	Mar. 6, 1884	Mar. 5, 1882	...do	...do	0.0	216	1,520	1.72	2,614
Do	Mar. 6, 1884	Mar. 5, 1882	Over levee	...do	0.0	400	400	2.58	1,032
Trotter's Landing	Mar. 6, 1884	Mar. 5, 1882	Over bank	...do	0.0	265	11,200	2.06	23,116

* This is an aggregate of the whole reach *i. e.*, where it is simply running over the levee. † Aggregate from McKinney's Bayou to Austin, where it is simply running over the levee. ‡ Levee back from the landing, in the woods.

Escape of the water of the Mississippi River into the swamps during the flood of 1884—Continued.

YAZOO BASIN FROM HORN LAKE TO HELENA—Continued.

Place.	Date of examination.	Date of opening of outlet.	Nature of outlet.	Direction of escape.	River below flood stage.	Width of outlet.	Area of outlet.	Reduced mean velocity per second.	Discharge through outlet per second.
					Feet.	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*
On Eagle Lake	Mar 8, 1884	Mar. 5, 1882	Crevasse	Into swamp	0.25	300	150	1.29	193
Do	Mar 8, 1884	Mar. 5, 1882	do	do	0.25	200	100	1.29	129
Do	Mar 8, 1884	Feb., 1882	do	do	0.25	200	800	1.72	1,376
Ferguson's Gin	Mar 8, 1884	Feb., 1882	do	do	0.25	262	1,980	2.75	5,448
Glendale	Mar. 8, 1884	Feb., 1882	do	do	0.25	110	1,950	1.97	3,857
Do	Mar. 8, 1884	Feb., 1882	do	From swamp into river.	0.25	118	1,330	3.09	4,117

YAZOO BASIN FROM HELENA TO VICKSBURG.

Place.	Date of examination.	Date of opening of outlet.	Nature of outlet.	Direction of escape.	River below flood stage.	Width of outlet.	Area of outlet.	Reduced mean velocity per second.	Discharge through outlet per second.
Thompson's Point No. 1	Mar. 8, 1884	Feb., 1882	Crevasse	Into swamp	0.25	1,825	6,820	4.88	33,020
Thompson's Point No. 2	Mar. 8, 1884	Feb., 1882	do	do	0.25	246	5,740	4.55	26,162
Dillard and Collin	Mar 8, 1884	Feb., 1882	do	do	0.25	557	8,633	6.88	60,308
[illegible]	Mar 8, 1884	Feb., 1882	do	do	0.25	498	4,966	6.88	34,300
Reed No. 1	Mar. 9, 1884	Feb., 1883	do	do	0.45	406	3,720	3.26	12,150
Reed No. 2	Mar 9, 1884	Feb., 1882	do	do	0.45	183	1,200	1.03	1,238
Reed No. 3	Mar 9, 1884	Feb., 1882	do	do	0.45	623	5,220	2.50	13,546
Faut's	Mar 9, 1884	Feb., 1882	do	do	0.45	448	3,920	4.30	16,856
Garth No. 1	Mar 9, 1884	Feb., 1882	Over levee	do	0.45	1,500	9,000	1.72	15,480
Garth No. 2	Mar 9, 1884	Feb., 1882	Crevasse	do	0.45	200	2,700	5.16	13,932
Garth No. 3	Mar 9, 1884	Feb., 1882	do	do	0.45	600	3,600	1.72	6,192
Garth No. 4	Mar 9, 1884	Feb., 1882	do	do	0.45	100	510	3.44	1,754
[illegible]	Mar 9, 1884	Feb., 1882	do	do	0.45	35	175	3.44	602
[illegible]	Mar 9, 1884	Feb., 1882	do	do	0.45	250	1,460	3.01	4,394
[illegible]	Mar. 9, 1884	Mar. 8, 1884	Over levee	do	0.45	100	600	1.72	1,032
[illegible]	Mar. 9, 1884	Mar 8, 1884	do	do	0.45	200	1,200	1.72	2,064
[illegible]	Mar. 9, 1884	Mar. 8, 1884	do	do	0.45	250	2,600	2.15	5,590
[illegible]	Mar. 9, 1884	Mar 8, 1884	do	do	0.45	125	700	3.44	2,614
[illegible]	Mar 9, 1884	Mar 8, 1884	do	do	0.45	108	1,240	2.58	3,199
[illegible]	Mar 9, 1884	Mar 8, 1884	do	do	0.45	10	10	0.86	8
McLeod's	Mar 8, 1884	Flood 1882	Crevasse	do	0.45	200	1,740	1.29	2,244
Do	Mar. 8, 1884	do	do	do	0.45	250	2,360	1.79	4,059
Do	Mar. 8, 1884	do	do	do	0.45	904	4,280	3.44	14,723
Do	Mar. 8, 1884	do	do	do	0.46	505	1,620	2.58	4,179
Do	Mar 10, 1884	do	do	do	0.2	303	2,420	3.52	8,533
Hughes*	Mar. 14, 1884	Feb. 29, 1884	do	do	0.1	707	9,880	4.64	45,882

* This break on Vermillion Lake.

TENSAS BASIN FROM CYPRESS CREEK TO RED RIVER LANDING.

Amos Ridge	Mar., 1884	In 1882	Over levee	Into swamp	0.10	7,000	4,900	6.88	†88,712
Boggy Bayou	Mar., 1884	do	Natural Bayou	do	0.10	250	8,000	6.88	55,040
On Cypress Creek	Mar., 1884	do	Over levee	do	0.10	1,100	1,820	3.44	4,540
Do	Mar., 1884	do	Crevasse	do	0.10	2,200	4,400	6.88	30,272
Do	Mar., 1884	do	do	do	0.10	800	5,600	6.88	38,528
Do	Mar., 1884	do	do	do	1.10	600	4,200	6.88	28,806
Do	Mar., 1884	do	do	do	0.1	700	14,000	1.72	24,080
Luoca Landing	Mar. 12, 1884	do	do	do	0.1	150	150	1.29	193
Do	Mar. 12, 1884	do	Over levee	do	0.1	200	200	1.29	258
Do	Mar. 12, 1884	do	do	do	0.1	150	150	1.29	193
Chicora	Mar. 12, 1884	do	Crevasse	do	0.1	100	8,800	2.58	2,270
Do	Mar. 12, 1884	do	Over levee	do	0.1	528	5,280	1.72	6,441
Do	Mar. 12, 1884	do	do	do	0.1	500	500	0.43	‡215
One mile below Charles City	Mar. 12, 1884	do	do	Into river	0.1	13,200	6,600	0.43	2,706
Arkansas City	Mar. 12, 1884	do	Crevasse	do	0.1	400	2,400	2.58	6,192
Do	Mar. 12, 1884	do	Regular Bayou	do	0.1	100	2,000	3.44	6,880
Do	Mar. 12, 1884	do	Over levee	Into swamp	0.1	10,000	2,500	1.72	4,300
Boggy Bayou	Mar. 12, 1884	do	Crevasse	do	0.1	141	141	3.44	485
Do	Mar. 12, 1884	do	do	do	0.1	50	240	4.21	1,011
Do	Mar. 12, 1884	do	do	do	0.1	30	30	2.15	64
Gaines's Landing	Mar. 12, 1884	do	do	do	0.1	25	25	2.15	53
Do	Mar. 12, 1884	do	do	do	0.1	183	2,780	2.35	9,324
Do	Mar. 12, 1884	do	do	do	0.1	50	75	2.58	183
Do	Mar. 12, 1884	do	do	do	0.1	100	150	2.58	387
Do	Mar. 12, 1884	do	do	do	0.1	100	200	2.58	516
Do	Mar. 12, 1884	do	do	do	0.1	25	75	3.44	258
Do	Mar. 12, 1884	do	do	do	0.1	108	980	2.15	2,107
Do	Mar. 12, 1884	do	do	do	0.1	75	562	2.58	1,451
Do	Mar. 12, 1884	do	do	do	0.1	50	25	1.72	43
Do	Mar. 12, 1884	do	do	do	0.1	100	200	1.72	344
Do	Mar. 12, 1884	do	do	do	0.1	100	2,600	2.58	670
Brooks's Saw-mill	Mar. 14, 1884	do	do	do	0.49	50	300	4.30	1,290
T. Cox's Point to Grand Lake	Mar. 14, 1884	do	Over bank	do	0.49	21,120	80,256	1.97	158,736
Grand Lake	Mar. 14, 1884	do	Crevasse	do	0.49	75	75	1.29	96
Cracroft	Mar. 15, 1884	do	Over bank	do	0.49	4,000	8,000	0.86	6,880
Near and above Graves's store	Mar. 15, 1884	do	Crevasse	Into river	0.49	10	10	0.86	8
Below Graves's store	Mar. 15, 1884	do	do	do	0.49	10	20	1.29	25
Do	Mar. 15, 1884	do	do	do	0.49	25	60	1.72	163
Do	Mar. 15, 1884	do	do	do	0.49	110	2,790	3.01	8,397
Do	Mar. 15, 1884	do	do	do	0.49	35	105	1.72	180
Do	Mar. 15, 1884	do	do	do	0.49	50	225	2.15	483
Do	Mar. 15, 1884	do	do	do	0.49	60	168	3.44	577
Do	Mar. 15, 1884	do	do	do	0.49	25	100	3.01	301
Do	Mar. 15, 1884	do	do	do	0.49	60	240	3.44	825
Do	Mar. 15, 1884	do	do	do	0.49	30	105	3.44	361
Do	Mar. 15, 1884	do	do	do	0.49	35	112	3.01	338
Half mile above Woodfork	Mar. 15, 1884	do	do	do	0.49	50	175	2.58	451

† Information received from Colonel Coleman. ‡ Aggregate.

Escape of the water of the Mississippi River into the swamps during the flood of 1884—Continued.

TENSAS BASIN FROM CYPRESS CREEK TO RED RIVER LANDING—Continued.

Place.	Date of examination.	Date of opening of outlet.	Nature of outlet.	Direction of escape.	River below flood stage.	Width of outlet.	Area of outlet.	Reduced mean velocity per second.	Discharge through outlet per second.
					Feet.	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*
Half mile above Woodfork	Mar. 15, 1884	In 1882	Crevasse	Into river	0.49	2,000	3,000	1.72	5,160
Hardscrabble	Mar. 20, 1884	do	Over bank	In swamp	0.3	4,000	14,400	1.63	23,529
Bougere, La., to Union Point	Mar. 20, 1884	do	do	do	0.3	21,120	89,337	1.29	115,781
Black Hawk to Point Breeze	Mar. 21, 1884	do	do	do	0.3	26,400	126,720	0.86	*108,979
Point Breeze to mouth of Old River	Mar. 21, 1884	do	do	Into river	0.3	31,680	63,360	0.86	*54,489
Old River	Mar. 21, 1884	1831.	Natural outlet	do	0.3	923	31,891	2.60	†85,823

ATCHAFALAYA BASIN FROM RED RIVER LANDING TO NEW ORLEANS.

Place.	Date of examination.	Date of opening of outlet.	Nature of outlet.	Direction of escape.	River below flood stage.	Width of outlet.	Area of outlet.	Reduced mean velocity per second.	Discharge through outlet per second.
Batchelor's Place	Mar. 23, 1884	Mar. 23, 1884	Crevasse	Into swamp	0.3	40	240	1.72	‡412
Morganza's Crevasse	Mar. 25, 1884	Mar. 14, 1884	do	do	0.3	1,902	31,880	6.62	211,109
Waterloo Crevasse	Mar. 25, 1884	Mar. 23, 1884	do	do	0.2	314	6,280	7.31	45,906
Belle Air Crevasse	Mar. 25, 1884	Mar. 18, 1884	do	do	0.2	255	1,620	8.60	13,932
Guidry's Crevasse No. 1	Mar. 26, 1881	Mar. 25, 1884	do	do	0.5	40	160	4.30	688
Guidry's Crevasse No. 2	Mar. 26, 1884	Mar. 25, 1884	do	do	0.5	150	525	5.16	2,709
Bayou La Fourche	Apr. 17, 1884	Mar. 25, 1884	Natural outlet	do	2.95	271	3,753	3.07	11,533
Davis Crevasse	Mar. 27, 1884	Mar. 15, 1884	do	do	0.5	557	11,640	12.9	§140,156

* Estimated. † Computed. ‡ Computed from a discharge taken January 16, 1882. § Depths estimated from shore and soundings.

Flood escape into the swamp basins during high water of 1884.

Basin.	Locality.	Distance.	Total sectional width.	Total sectional area.	Total discharge, cubic feet per second.
		Miles.	*Feet.*	*Sq. feet.*	
Yazoo	Horn Lake to Helena, outflow	82. 1	42, 100	154, 030	340, 231
Do	Horn Lake to Helena, return flow		8, 797	30, 999	76, 341
Do	Horn Lake to Helena, net escape				263, 890
Do	Helena to Vicksburg, outflow*	292. 6	10, 349	86, 195	334, 184
Total escape into Yazoo Basin					598, 074
Tensas	Cypress Creek to Ashton, outflow	94. 5	56, 419	156, 715	412, 843
Do	Cypress Creek to Ashton, return flow		14, 190	15, 110	27, 894
Do	Cypress Creek to Ashton, net escape				384, 949
Do	Ashton to Red River Landing, outflow	244. 8	51, 520	230, 458	248, 290
Do	Ashton to Red River Landing, return flow		32, 608	95, 251	140, 313
Do	Ashton to Red River Landing, net escape				107, 977
Total escape into Tensas Basin					492, 926
Atchafalaya	Red River Landing to New Orleans, outflow*	198. 3	8, 533	56, 096	426, 447

* No return flow.

Table giving maximum gauge heights and dates on which the river obtained flood stage at various points on the Mississippi River in 1882, 1883, and 1884.

Place.	Date.	Gauge height.	Date.	Gauge height.	Date.	Gauge height.
	1882.	*Feet.*	1883.	*Feet.*	1884.	*Feet.*
Saint Louis, Mo	July 5	32. 20	June 26	34. 60		
Rush Tower, Mo	July 5	37. 50			April 11	34. 70
Grand Eddy, Mo	July 6	39. 10	June 27	41. 92	Apr. 10–11	38. 35
Gray's Point, Mo					April 11	28. 17
Cairo, Ill	Feb. 26	51 87	Feb. 27	52. 17	Feb. 22–24	51. 79
Columbus, Ky	Feb. 26	102. 79	Feb. 27	103. 046	Feb. 23–24	103. 80
New Madrid, Mo	[illegible] 27	41 615	Feb. 28	42. 020	Feb. 24	41. 50
Cottonwood Point, Mo	Feb. 28	37 50	Feb. 28	37. 65	Feb. 24–26	37. 45
Fulton, Tenn	Mar. 1	36. 69	Feb. 28	36. 29	Feb. 26–29	35. 68
Memphis, Tenn	Mar. 9	35. 15	[illegible] 6	34. 75	March 1	34. 15
Mhoon's, Miss	Mar. 9	39. 80	Mar. 8	40. 20	March 5–6	38. 90
Helena, Ark	Mar. 9	47 20	Mar. 9	46. 90	March 6	47. 00
Saint Louis Landing, Ark	Mar. 9		Mar. 10	41. 75	March 6–7	48. 20
Mouth of White River	Feb. 28	48. 40	Mar. 10	48. 00	March 7–8	47. 90
Arkansas City, Ark	Feb. 28	47 00	Mar. 10	46. 32	March 7–9	46. 50
Greenville, Miss	Feb. 27	41 68	Mar. 12	40 40	March 8	41. 10
Lake Providence, La	Mar. 20	38. 32	Mar. 12	36. 47	Mar 23–24	38. 40
Vicksburg, Miss	Mar. 20	48. 75	Apr. 7	43. 80	March 25	49. 00
Saint Joseph, La	Mar. 20	44 90	Apr. 7	41. 90	March 24	44. 89
Natchez, Miss	Mar. 28	47. 75	Apr. 7	44. 00	Mar. 24–26	47. 46
Red River Landing, La	Mar. 27	48. 50	Apr. 9	45. 20	Mar 29–31	47. 30
Port Hickey, La	Mar. 28	47. 90	Mar. 15	47. 47	March 29	47 42
Baton Rouge, La	Mar. 21	35. 95	Apr. 9	35. 06	March 24	36. 20
Plaquemine, La	Mar. 21	31 30	Apr. 9	30. 73	March 30	31. 60
College Point, La	Mar. 22	23. 07	Apr. 9	[illegible]	March 24	24. 05
Carrollton, La	Mar. 21	14. 96	Apr. 7	[illegible]	March 18	15. 60

Table of discharges taken by Patrol party during the flood of 1884.

River.	Locality.	Date.	Gauge-reading.	Place.	Discharge in cubic feet per second.	Area in square feet.	Mean velocity in feet per second.
		1884.					
Saint Francis....	Westbrook, Ark	Mar. 4	38.80	Mhoon's........	135, 651	26, 254	5, 167
Mississippi	Hays' Landing, Miss..	Mar. 16	37 72	Hays'...........	1, 066, 758	171, 253	6, 229
Yazoo	Near Chick. Bayou ..	Mar 18	46.50	Vicksburg......	161, 822	42, 253	3, 818
Mississippi	Red River Landing, La	Mar 21	46.05	Red River Landing.	1, 291, 625	228, 280	5, [illegible]
Bayou LaFourche	Near Thibodeaux, La..	Apr. 14	22.20	College Point...	11, 583	2, 752	4, 070
Mississippi	Carrollton, La ...	Apr 15	14.15	Carrollton	892, 862	197, 317	4, [illegible]

NOTE.—Column headed "Place" refers to column headed "Gauge."

APPENDIX B.

PRECISE LEVELS—REPORTS AND RESULTS.

1.—*Final reduction and results of precise levels from Fulton to Chicago, Ill.*

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., October 9, 1883.

SIR: I have the honor to submit the following report on the reduction of the notes of the precise leveling from Fulton, Ill., to Chicago.

The office computation has been made by Assistants Ferguson, Fitzhugh, Thomas, and Kastl. The methods of reduction employed are the same as those used in the reduction of the notes of the precise leveling from Carrollton, La., to Biloxi, Miss.

The following are the values of instrumental constants used:

Correction for inequality of pivots in millimeters, per meter:

Level No. 1 p = from —.015 to + .005.
Level No. 3 p = from — .006.
Level No. 5 p = from — .010.

Assistant J. B. Johnson used level tube No. 5 and level instrument No. 3 throughout the season, with the exception of having used the telescope barrel (not the reticule) of level instrument No. 5 from June 7 to end of season.

Value of one division of tube No. 3, $v = 2''.44$.
Value of one division of tube No. 5, $v = 2''.54$.

The mean value of 1 meter of the four rods used, Nos. 14, 15, 16, and 17, is 1.000029 meters, which value results from comparisons made August, 1882, with 1 meter bar, rods at a mean temperature of 73° F.

Assistant J. B. Johnson also made a determination of the lengths of the above rods in December, 1882, by comparison with the 15-foot bar of the Lake Survey Office. The rods were at a temperature of 54° F., and the mean value then found was 0.999950 meters, which differs from the comparisons used by 0.000079 meters. Part of this discrepancy, I think, is to be accounted for by the difference in temperature (19° F.) of the rods themselves. I believe there was no correction made for coefficient of expansion of the wood. Using the same as for white pine given by Trautwine, .0000022, the correction for temperature will be 0.000042 meters. Applying this the discrepancy between the August and December determinations is only 0.000037 meters. I believe there were also no observations taken for humidity of the atmosphere, which influences the change in length of wood more than change in temperature. The August observations were taken in basement, the December observations were taken in commissioner's room, on second floor. The maximum rod correction used was 3.[illegible] millimeters.

The following were the distances from the foot of the rods to the 100 millimeter mark of graduation:

	Millimeters.
Rod 14	44.
Rod 15	44.
Rod 16	44.
Rod 17	44.

May 8, 1883, the rods were ground off to a uniform length of 44.2 millimeters. Up to May 8 corrections were made in this computation for the difference of length of rods whenever a stretch was not closed with the same rod as it was started with. After this date no correction was necessary.

The tabulation of the results of the final reduction is given on pages 24 to 40, inclusive. All elevations are referred to Cairo datum and start with the elevation of U. S. P. B. M. 53, near Albany, Ill. As 188.6009 meters (see Annual Report for 1883, page 128), on account of U. S. P. B. M 55, of the Keokuk and Fulton line, having been disturbed or at least meddled with, the field tabulation was started with elevation of U. S. P. B. M. 56, next beyond (183.6809 meters), but the Keokuk to Fulton line was duplicated from U. S. P. B. M. 53 to U. S. P. B. M. 56. The former line of levels over this stretch was more concordant than the latter. At U. S. P. B. M. 56, a distance of 5.9 kilometers, the lines diverged by 6.2 millimeters, our elevation of U. S. P. B. M. 56, as run from U. S. P. B. M. 53, in 1883, being 6.2 millimeters lower; however, as U. S. P. B. M. 53 was considered more permanent than U. S. P. B. M. 56, it was thought best in the office reduction to continue the Keokuk-Fulton elevations from U. S. P. B. M. 53. This was done. However, it is questionable if the mean of the two lines from U. S. P. B. M. 53 to U. S. P. B. M. 56 would not be better.

In connecting Chicago benches with city directrix the levels were carried from shore to the zero of our temporary gauge on outside of crib by comparing the readings of this gauge successively with the readings of three temporary gauges on shore widely separate. These were combined with equal weight with a determination made by the city engineer in December, 1878, using Hook gauges, reading by Vernier to 0.001 foot. These were carried through the tunnel, all pumping (and therefore all current) having ceased. The elevations are carried from the zero of the outer gauge to city directrix, a point 8.01 feet below the zero of the inner crib gauge, by spirit-levels.

The work for the season is as follows:

	Kilometers.
Distance of main line duplicated	261.36
Side	13.43
	274.79

(All side line duplicated except 1.71 kilometers, which was only run one way.)

Length of repeated duplicate work:

	Kilometers.
3 lines	2.19
4 lines	28.28
5 lines	2.01
6 lines	0.73
8 lines	2.15
	35.36

Total length of single line, 628.49 kilometers.

The probable error of the whole line of levels from Fulton to Chicago on the terminal benches at Chicago is 13.6 millimeters. This is computed by considering all discrepancies as accidental, the square root of the sum of the squares then remaining uncompensated. There are, however, constant errors or accumulating errors, which is the algebraic sum of the personal errors of the members of the party concerned in carrying the levels. This constant error changes very materially on account of the following conditions: (1) Owing to the nature of the ground; (2) owing to the nature of the weather; and (3) owing to the changing habits of the members concerned. It is therefore next to impossible to obtain any approximate measure of it. We are quite safe to assume that it remains approximately constant for any and perhaps every one of our various stretches. And since the functions from which we compute the probable error of final result (R. = 13.6 millimeters) are the discrepancies (regardless of sign) of the two lines run by the same observer in opposite directions, we are safe to assume that 13.6 millimeters is considerably too large. This has only a theoretical interest, since in taking the mean of the two lines run in this way, for the difference of elevations, the constant is eliminated. But assuming again all errors to be accidental, we may compute the probable error per kilometer.

x = probable error per kilometer.
R = probale error of final result.
D = distance in kilometers.

$$R^2 = X^2D. \qquad D = 261.36. \qquad x = \frac{R}{\sqrt{D}} \qquad R = 13.6. \quad \sqrt{D} = 16.17.$$

$$\text{Therefore probable error per kilometer} = \frac{13.6}{16.17}$$

In columns headed "Supports" in tabulation the letters F and P denote foot-plates and pins, respectively, used as rod supports.

In the columns headed "Observer", the observers are represented by letters, as follows: "J" represents J. B. Johnson; "F" represents O. W. Ferguson.

Benches marked with a star (*) are not in the main line. All quantities in the tabulation have been checked either by comparison with the field computation or by computation duplicated by two computers.

Very respectfully, your obedient servant,

O. W. FERGUSON,
U. S. Assistant Engineer.

First Lieut. SMITH S. LEACH,
Secretary Mississippi River Commission.

Results of precise leveling, Fulton to Chicago, Ill.

[Bench-marks marked with an asterisk are not in main line of levels.]

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
U. S. P. B. M. 53	0								188.6009		
T. B. M. 1 and 1 *a*	1.14	N	−4.1316	−0.9	0.6		184.4684			F.	J.
		S	−4.1334	+0.9						F.	J.
		Mean	−4.1325								
T. B. M. 2	2.12	N	−1.4160	−1.8	1.3		183.0506			F	F.
		S	−1.4195	+1.7						F.	F.
		Mean	−1.4178								
T. B. M. 4 and 4 *a*	3.81	N	+2.7473	−0.3	0.2		185.7976			P.	F.
		S	+2.7466	+0.4						F.	F.
		Mean	+2.7470								
T. B. M. 5	5.08	N	−0.7441	−0.8	1.4		185.0527			F.	J.
		S	−0.7508	+5.9						F.	J.
		N	−0.7435	−1.4						F.	J.
		S	−0.7412	−3.7						F.	J.
		Mean	−0.7449								
U. S. P. B. M. 55	5.71	N	−1.7640	+0.4	0.8	2.0	183.2891	−0.2	183.2889	F.	J.
		S	−1.7631	−0.5						F.	J.
		Mean	−1.7636								
U. S. P. B. M. 56	5.93	N	+0.3859	−0.3	0.2		183.6747	−0.1	183.6746	F.	J.
		S	+0.3853	+0.3		2.0				F.	J.
		Mean	+0.3856								
T. B. M. 6 and 6 *a*	7.02	N	+2.2218	−0.8	0.5		185.8957			F.	J.
		S	+2.2127†							F.	J.
		N	+2.2191	+1.9						F.	J.
		S	+2.2228	−1.8						F.	J.
		S	+2.2203	+0.7							J.
		Mean	+2.2210								
T. B. M. 9 and 9 *a*	9.55	N	−0.5814	−1.3	0.6		185.3131			F.	F.
		S	−0.5838	+1.2						F.	F.
		Mean	−0.5826								
*U. S. P. B. M. 57 Fulton, Ill.		W	+2.8756	−1.1	0.7	2.3	188.1876	0.0	188.1876	F.	F
		E	+2.8734	+1.1						F.	F.
		Mean	+2.8745								

† Rejected.

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
of L. & H. Co.,		W	—5. 9720	—0. 4	0. 3		182. 2152	—0. 2	183. 2150	F.	F.
;er gauge at		E	—5. 9728	+0. 4						F.	F.
ton, Ill., 10											
. above low		Mean	—5. 9724								
;er of 1877.											
35, Capt. Mac-		E	—3. 4085				184. 7791	—0. 1	184. 7790	F.	F.
nie, Fulton.											
water 1877			—9. 0204				179. 1672	—0. 3	179. 1669	F.	F.
water 1828			—2. 8991				185. 2885	—0. 1	185. 2884	F.	F
water 1859			—3. 4959				184. 6917	—0. 1	184. 6916	F.	F.
water of April 1870.			—3. 2800				184. 9076	—0. 1	184. 9075	F.	F.
water of June 1880.			—3. 0261				185. 1615	—0. 1	185. 1614	F.	F.
water of Octo- 1881.			—3. 2674				184. 9202	—0. 1	184. 9201	F.	F.
B. M. 56, Ful-	10. 52	N	—1 5622	—0. 5	0. 3	2. 2	183. 7504	—0. 1	183. 7503	F.	F.
Junction.		S	—1. 5633	+0. 5						F.	F.
		Mean	—1. 5627								
[. 12 and 12 a	12. 05	N	+1. 4151	0. 0	0. 0		185. 1655			F.	F.
		S	+1. 4151	0. 0						F.	F.
		Mean	+1 4151								
[. 14	14. 42	N	+0. 5039	+0. 2	0. 1		185. 6696			F.	J.
		S	+0. 5043	—0. 2						F.	J.
		Mean	+0. 5041								
B. M. 50	14. 50	N	+0. 1580	0. 0	0. 0	2. 2	185. 8270	—0. 1	185. 8275	F.	J.
		S	+0 1580	0. 0						F.	J.
		Mean	+0. 1580								
[. 15 and 15 a	15. 39	N	+2. 3443	0. 0	0. 0		188. 1719			F.	J
		S	+2. 3443	0. 0						F.	J.
		Mean	+2 3443								
[. 16 and 16 a	16. 61	N	+1. 3281	+0. 3	0. 2		189. 5003			F.	J.
		S	+1 3288	—0. 4						F.	J.
		Mean	+1 3284								
[. 17 and 17 a	17. 99	N	+4. 6185	+1. 2	0. 8		194. 1200			F.	F.
		S	+4. 6209	—1. 2						F.	F.
		Mean	+4 6197								
[. 18 and 18 a	18. 82	N	—1 8191	—0. 8	0. 5		192. 3001			F.	F.
		S	—1 8207	+0. 8						F.	F.
		Mean	—1. 8199								
[. 20 and 20 a	21. 02	N	—2 1712	—1. 8	1. 3		190. 1271			F.	J.
		S	—2. 1748	+1. 8						F.	J.
		Mean	—2. 1730								
[. 21 and 21 a	21. 57	N	+0. 3084	—0. 1	0. 1		190. 4354			F.	F.
		S	+0. 3082	+0. 1						F.	F.
		Mean	+0. 3083								
P. B. M. 60,		E	+0 4246	—0. 4	0. 3	2. 7	190. 8596	+0. 1	190. 8597	F.	F.
;mson, Ill.		W	+0. 4237	+0. 5						F.	F.
		Mean	+0. 4242								
[. 23 and 23 a	23. 86	N	+0 1223	—0. 3	0. 2		190. 5574			F.	F.
		S	+0. 1216	+0. 4						F.	F.
		Mean	+0. 1220								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
T. B. M. 24	25. 04	N	—0. 1848	—1. 1	1. 4		190. 8715			F.	J.
		S	—0. 1907	+4. 8						F.	J.
		N	—0. 1808	—5. 1						F.	J.
		S	—0. 1872	+1. 3						F.	J.
		Mean	—0. 1859								
T. B. M. 25 and 25 *a*	25. 84	N	—0. 0195	—0. 9	0. 6		190. 8511			F.	J.
		S	—0. 0214	+1. 0						F.	J.
		Mean	—0. 0204								
T. B. M. 26 and 26 *a*	26. 60	N	+0. 5084	—1. 2	0. 8		190. 8583			F.	J.
		S	+0. 5059	+1. 3						F.	J.
		Mean	+0. 5072								
T. B. M. 27 and 27 *a*	28. 02	N	—0. 1509	+0. 6	0. 4		190. 7080			F.	F.
		S	—0. 1497	—0. 6						F.	F
		Mean	—0. 1503								
T. B. M. 28 and 28 *a*	28. 95	N	+1. 2156	—2. 0	1. 3		191. 9216			F.	J.
		S	+1. 2117	+1. 9						F.	J.
		Mean	+1. 2136								
T. B. M. 30 and 30 *a*	31. 32	N	+0. 0589	+3. 5	2. 4		191. 9840			F.	F.
		S	+0. 0660	—3. 6						F.	F.
		Mean	+0. 0624								
T. B. M. 32 and 32 *a*	33. 16	N	—5. 8730	+0. 4	0. 2		186. 1114			F.	J.
		S	—5. 8723	—0. 3						F.	J.
		Mean	—5. 8726								
T. B. M. 34 and 34 *a*	34. 88	N	—0. 9933	+2. 5	1. 7		185. 1206			F.	F.
		S	—0. 9883	—2. 5						F.	F.
		Mean	—0. 9908								
T. B. M. 35	35. 71	N	+0. 1533	+0. 5	0. 3		185. 2744			F.	F.
		S	+0. 1543	—0. 5						F.	F.
		Mean	+0. 1538								
*U. S. P. B. M. 61		E	—0. 2706	—0. 2	0. 1	4. 6	185. 0036	—0. 1	185. 0035	F.	F.
		W	—0. 2710	+0. 2						F.	F.
		Mean	—0. 2708								
T. B. M. 37	36. 83	N	+1. 2646	—2. 4	1. 6		186. 5366			F.	J.
		S	+1. 2599	+2. 3						F	J.
		Mean	+1. 2622								
*T. B. M. 38 and 38*a*		N	—0. 1310	+1. 3	0. 9		186. 4069			F.	F.
		S	—0. 1284	—1. 3						F.	F.
		Mean	—0. 1297								
*U. S. P. B. M. 62, at Savanna, Ill.		N	+0. 1711	—0. 1	0. 1	4. 9	186. 5779	—0. 1	186. 5778	F.	F.
		N	+0. 1709	+0. 1						F.	J.
		Mean	+0. 1710								
*U. S. P. B. M. 63, at Savanna, Ill.		E	+2. 4468	0. 0	0. 0	4. 9	188. 8537	0. 0	188. 8537	F.	F.
		W	+2. 4468	0. 0						F.	F.
		Mean	+2. 4468								
*B. M. 34 of Captain Mackenzie, Savanna, Ill.		N	+0. 1715	+0. 5	0. 3	4. 9	186. 5789	—0. 1	186. 5788	F.	F.
		N	+0. 1725	—0. 5						F.	J.
		Mean	+0. 1720								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		M.	Mm.	Mm.	Mm.	M.	Mm.	M.		
water of June 1880, Savanna,		N.	+0.2948	—4.6	3.0		186.6971	—0.1	186.6970	F.	F.
		N.	+0.2857	+4.5						F.	J.
		Mean.	+0.2902								
water of Octo- 26, 1881, Sa- na, Ill.		N.	−0.0162	+9.7	6.5		186.4004	—0.1	186.4003	F.	F.
		N.	+0.0032	—9.7						F.	J.
		Mean.	−0.0065								
M. 39 and 39 a	37.89	N.	—0.1102	+0.2	0.1		186.4266			F.	J.
		S.	—0.1098	—0.2						F.	J.
		Mean.	—0.1100								
M. 40 and 40 a	39.21	E.	+0.2248	+1.2	0.8		186.6526			F.	F.
		W.	+0.2272	—1.2						F.	F.
		Mean.	+0.2260								
P. B. M. 64, n River.	40.90	E.	+0.4294	+2.6	1.7	5.2	187.0846	0.0	187.0846	F.	F.
		W.	+0.4345	—2.5						F.	F.
		Mean.	+0.4320								
M. 41 and 41 a	42.42	E.	+13.6982	+1.0	0.7		200.7838			F.	J.
		W.	+13.7003	—1.1						F.	J.
		Mean.	+13.6992								
M. 42	43.87	E.	+10.1222	+2.2	1.4		210.9082			F.	J.
		W.	+10.1265	—2.1						F.	J.
		Mean.	+10.1244								
P. B. M. 65		N.	+0.5942	—0.4	0.3	5.4	211.5020	+0.7	211.5027	F.	F.
		W.	+0.5933	+0.5						F.	F.
		Mean.	+0.5938								
M. 43 and 43 a	45.19	E.	+7.0019	+2.7	1.8		217.9128			F.	J.
		W.	+7.0072	—2.6						F.	J.
		Mean.	+7.0046								
M. 44	46.50	E.	+7.4844	—4.2	1.8		225.3930			F.	F.
		W.	+7.4749	+5.3						F.	F.
		E.	+7.4800	+0.2						F.	F.
		W.	+7.4815	—1.3						F.	F.
		Mean.	+7.4802								
M. 45	47.79	E.	+12.7588	—0.2	0.1		238.1516			F.	F.
		W.	+12.7584	+0.2						F.	F.
		Mean.	+12.7586								
M. 46 and 46 a	48.96	E.	+8.4980	—1.6	1.0		246.6480			F.	F.
		W.	+8.4949	+1.5						F.	F.
		Mean.	+8.4964								
M. 47 and 47 a	50.39	E.	+0.5278	+0.9	0.6		247.1767			F.	J.
		W.	+0.5296	—0.9						F.	J.
		Mean.	+0.5287								
M. 48 and 48 a	51.22	E.	—3.4139	—1.4	0.9		243.7614			F.	J.
		W.	—3.4167	+1.4						F.	J.
		Mean.	—3.4153								
M. 49 and 49 a	52.20	E.	+3.4158	—1.0	0.7		247.1762			F.	F.
		W.	+3.4138	+1.0						F.	F.
		Mean.	+3.4148								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
T. B. M. 50	53.84	E	+7.1070	+0.4	0.3		254.2836			F.	F.
		W	+7.1079	−0.5						F.	F.
		Mean	+7.1074								
*U. S. P. B. M. 66. Mount Carroll.		E	+0.8273			6.1	255.1109	+1.9	255.1128	F.	J.
T. B. M. 51 and 51 *a*	55,47	E	+2.5919	+1.1	6.7		256.8766			F.	J.
		W	+2.5940	−1.0						F.	J.
		Mean	+2.5930								
T. B. M. 52 and 52 *a*	56.86	E	−2.1243	+0.8	0.5		254.7531			F.	J.
		W	−2.1227	−0.8						F.	J.
		Mean	−2.1235								
T. B. M 53 and 53 *a*	57.38	E	+3.4413	−0.3	0.2		258.1941			F.	F.
		W	+3.4406	+0.4						F.	F.
		Mean	+3.4410								
T. B. M. 55	59.77	E	−11.2762	+1.8	1.2		246.9197			F.	F
		W	−11.2727	−1.7						F.	F
		Mean	−11.2744								
*U. S. P. B. M. 67		E	−0.4090	−0.2	0.1	6.3	246.5105	+1.7	246.5122	F.	J
		W	−0.4094	+0.2						F.	F
		Mean	−0.4092								
T. B. M. 56	61.02	E	−2.0057	−1.3	0.9		244.9127			F.	[illegible]
		W	−2.0083	+1.3						F.	[illegible]
		Mean	−2.0070								
T. B. M. 57 and 57 *a*	62.21	E	+11.2393	−1.3	0.9		256.1507			F.	[illegible]
		W	+11.2367	+1.3						F.	[illegible]
		Mean	+11.2380								
T. B. M. 58	62.96	E	+7.4822	0.0	0.0		263.6329			F.	[illegible]
		W	+7.4822	0.0						F.	[illegible]
		Mean	+7.4822								
T. B. M. 59 and 59 *a*	63.39	E	+3.3855	+0.4	0.3		267.0188			F.	[illegible]
		W	+3.3863	−0.4						F.	[illegible]
		Mean	+3.3859								
T. B. M. 61 and 61 *a*	66.12	E	+7.6466	−0.6	0.4		274.6648			F.	[illegible]
		W	+7.6455	+0.5						F.	[illegible]
		Mean	+7.6460								
*U. S. P. B. M. 68, at Lanark, Ill.		E	+0.6166	+0.2	0.1	6.4	275.2816	+2.5	275.2841		[illegible]
		W	+0.6170	−0.2							[illegible]
		Mean	+0.6168								
T. B. M. 62	67.00	E	−5.0568	+2.2	0.8		269.6102			P.	[illegible]
		W	−5.0517	−2.9						F.	[illegible]
		E	−5.0542	−0.4						P.	[illegible]
		W	−5.0559	+1.3						P.	[illegible]
		Mean	−5.0546								
T. B. M. 63 and 63 *a*	67.60	E	−4.0752	−0.3	0.2		265.5347			P.	[illegible]
		W	−4.0758	+0.3						P.	[illegible]
		Mean	−4.0755								

***Results of precise leveling, Fulton to Chicago, Ill.*—Continued.**

Bench.	Distance.	Direction.	Difference of elevation.	v	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*		*Mm.*	*M.*		
. 64 and 64 *a* ..	69. 00	E	—6. 7111	0. 0	0. 7	......	258. 8236	......	....	F.	J.
		W	—6. 7137	+2. 6	......	......	....	......	....	F.	J.
		E	—6. 7088	—2. 3	......	......	....	......	....	P.	J.
		W	—6. 7109	0. 2	......	......	....	......	....	P.	J.
		Mean	—6. 7111								
B. M. 65, Lan-unction.	70. 79	E	+3. 3617	—2. 9	1. 9	6. 8	262. 1824	+2. 1	262. 1845	P.	J.
		W	+3. 3559	+2. 9	......	......	....	......	....	P.	J.
		Mean	+3. 3588								
. 66	71. 70	E	+2. 2897	+4. 4	......	......	....	......	....	P.	F.
		W	+2. 2979	—3. 8	1. 1	......	264. 4765	......	....	P.	F.
		E	+2. 2950	—0. 9	......	......	....	......	....	P.	F.
		W	+2. 2937	+0. 4	......	......	....	......	....	P.	F.
		Mean	+2. 2941								
. 67 and 67 *a* ..	72. 71	E	+2. 6819	+1. 3	0. 9	......	267. 1597	......	....	P.	F.
		W	+2. 6846	—1. 4	......	......	....	......	....	P.	F.
		Mean	+2. 6832								
. 68	73. 57	E	+2. 7432	—0. 1	0. 1	......	269. 9028	......	....	F.	F.
		W	+2. 7430	+0. 1	......	......	....	......	....	F.	F.
		Mean	+2. 7431								
. 69 and 69 *a* ..	74. 49	E	+3. 0886	+2. 4	0. 6	......	272. 9938	......	....	F.	F.
		W	+3. 0928	—1. 8	......	......	....	......	....	F.	F.
		E	+3. 0917	—0. 7	......	......	....	......	....	F.	F.
		W	+3. 0908	+0. 2	......	......	....	......	....	F.	F.
		Mean	+3. 0910								
. 71 and 71 *a* ..	76. 91	E	+18. 8506	—1. 9	1. 3	......	291. 8424	......	....	F.	J.
		W	+18. 8466	+2. 0	......	......	....	......	....	F.	J.
		Mean	+18. 8486								
. 72	77. 35	E	+2. 3042	+0. 2	0. 3	......	294. 1468	......	....	F.	J.
		W	+2. 3047	—0. 3	......	......	....	......	....	F.	J.
		Mean	+2. 3044								
. B. M. 70	.....	E	+0. 6898	—0. 2	0. 1	7. 1	294. 8364	+3. 1	294. 8395	F.	J.
		W	+0. 6895	+0. 1	......	......	....	......	....	F.	J.
		Mean	+0. 6896								
. 73 and 73 *a* .	77. 81	E	+4. 4521	—1. 9	0. 6	......	298. 5970	......	....	F.	J.
		W	+4. 4480	+2. 2	......	......	....	......	....	F.	J.
		E	+4. 4510	—0. 8	......	......	....	......	....	F.	J.
		W	+4. 4499	+0. 4	......	......	....	......	....	F.	J.
		Mean	+4. 4502								
. 74	78. 74	E	+2. 2901	—1. 9	1. 3	......	300. 8852	......	....	F.	J.
		W	+2. 2863	+1. 9	......	......	....	......	....	F.	J.
		Mean	+2. 2882								
. 75 and 75 *a* ..	79. 72	E	—3. 1615	+4. 2	0. 3	......	297. 7279	......	....	F.	J.
		W	—3. 1520	—5. 3	......	......	....	......	....	F.	J.
		E	—3. 1611	+3. 8	......	......	....	......	....	F.	J.
		W	—3. 1534	—3. 9	......	......	....	......	....	F.	J.
		E	—3. 1585	+1. 2	......	......	....	......	....	F.	J.
		W	—3. 1598	+2. 5	......	......	....	......	....	F.	J.
		E	—3. 1560	—1. 8	......	......	....	......	....	F.	F.
		W	—3. 1564	—0. 9	......	......	....	......	....	F.	F.
		Mean	—3. 1573								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
T. B. M. 77 and 77 *a*..	82.04	E.....	—8.1441	—2.7	1.8	......	289.5811	......	....	F.	F.
		W	—8.1496	+2.8	......	......	....	......	....	F.	F
		Mean .	—8.1468								
T. B. M, 78 and 78 *a*..	83.03	E.....	+1.7236	—0.9	0.6	......	291.3038	......	....	F.	F.
		W	+1.7218	+0.9	......	......	....	......	....	F.	F.
		Mean .	+1.7227								
T. B. M. 80 and 80 *a*..	85.24	E.....	—4.6831	+1.5	1.0	......	286.6222	......	....	F.	F.
		W	—4.6801	—1.5	......	......	....	......	....	F.	F.
		Mean .	—4.6816								
U. S. P. B. M. 71, Forreston Junction.	87.99	E.....	—13.2258	—1.0	0.7	7.6	273.3954	+2.5	273.3979	F.	J.
		W	—13.2279	+1.1	......	......	....	......	....	F.	J.
		Mean .	—13.2268								
T. B. M. 84 and 84 *a*..	90.05	E.....	—10.9234	+1.4	1.0	......	262.4734	......	....	F.	J.
		W	—10.9205	—1.5	......	......	....	......	....	F.	J.
		Mean .	—10.9220								
T. B. M. 85	91.23	E.....	—1.9385	—0.9	0.6	......	260.5340	......	....	F.	F.
		W	—1.9403	+0.9	......	......	....	......	....	F.	F.
		Mean .	—1.9394								
T. B. M. 86 and 86 *a*..	92.04	E.....	—0.3271	—0.1	0.0	......	260.2068	......	....	F.	F.
		W	—0.3272	0.0	......	......	....	......	....	F.	F.
		Mean .	—0.3272								
T. B. M. 87	92.68	E.....	+1.1567	—0.1	0.0	......	261.3634	......	....	F.	F.
		W	+1.1566	0.0	......	......	....	......	....	F.	F.
		Mean .	+1.1566								
T. B. M. 88 and 88 *a*..	93.56	E.....	—5.7337	+2.5	0.9	......	255.6322	......	....	F.	F.
		W	—5.7289	—2.3	......	......	....	......	....	F.	F.
		E.....	—5.7309	—0.3	......	......	....	......	....	F.	F.
		Mean .	—5.7312								
T. B. M. 90 and 90 *a*..	95.04	E....	—11.5999	—1.1	0.7	......	244.0312	......	....	F.	J.
		W	—11.6020	+1.0	......	......	....	......	....	F.	J.
		Mean .	—11.6010								
T. B. M. 92	96.89	E.....	—10.4866	+1.2	0.8	......	233.5458	......	....	F.	J.
		W	—10.4843	—1.1	......	......	....	......	....	F.	J.
		Mean .	—10.4854								
* U. S. P. B. M. 72, at Adeline, Ill.	....	E.....	+1.3836	......	......	7.8	234.9294	+1.3	234.9307	F.	J.
T. B. M., 93 and 93 *a*.	97.55	E....	—0.1397	—1.3	0.9	......	233.4048	......	....	F.	J.
		W	—0.1423	+1.3	......	......	....	......	....	F.	J.
		Mean .	—0.1410								
T. B. M. 95 and 95 *a*..	99.65	E. ...	—5.7039	—0.8	0.5	......	227.7001	......	....	F.	F.
		W	—5.7055	+0.8	......	......	....	......	....	F.	F.
		Mean .	—5.7047								
T. B. M. 96 and 96 *a*..	100.76	E.....	—1.8277	—0.1	0.1	......	225.8723	......	....	F.	F.
		W	—1.8279	+0.1	......	......	....	......	....	F.	F.
		Mean .	—1.8278								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
T. B. M. 97 and 97 *a*	101.98	E	−2.0460	+0.4	0.3		223.8267			F.	J.
		W	−2.0451	−0.5						F.	J.
		Mean	−2.0456								
T. B. M. 99 and 99 *a*	104.22	E	−2.6565	−1.9	1.3		221.1683			F.	J.
		W	−2.6603	+1.9						F.	J.
		Mean	−2.6584								
*U. S. P. B. M. 73, Leaf River, Illinois.			+1.0253			8.0	222.1936	+1.0	222.1946	F.	J.
T. B. M. 100	105.37	E	+0.3356	−2.1	1.4		221.5018			F.	F.
		W	+0.3314	+2.1						F.	F.
		Mean	+0.3335								
T. B. M. 101 and 101 *a*	106.45	E	+5.8408	−2.6	1.2		227.3400			F.	F.
		W	+5.8336	+4.6						F.	F.
		E	+5.8375	+0.7						F.	F.
		W	+5.8408	−2.6						F.	F.
		Mean	+5.8382								
T. B. M. 102 and 102 *a*	107.82	E	+12.1655	−0.1	0.0		239.5054			F.	J.
		W	+12.1654	0.0						F.	J.
		Mean	+12.1654								
T. B. M. 105 and 105 *a*	111.05	E	−4.8799	−2.1	1.4		234.6234			F.	J.
		W	−4.8842	+2.2						F.	J.
		Mean	−4.8820								
T. B. M. 106	112.22	E	−7.7454	+1.8	1.0		226.8798			F.	F.
		W	−7.7393	−4.3						F.	F.
		E	−7.7454	+1.8						F.	F.
		W	−7.7443	+0.7						F.	F.
		Mean	−7.7436								
T. B. M. 107	113.33	E	−7.9777	+2.0	0.8		218.9041			F.	F.
		W	−7.9724	−3.3						F.	F.
		E	−7.9767	+1.0						F.	F.
		W	−7.9760	+0.3						F.	F.
		Mean	−7.9757								
T. B. M. 108 and 108 *a*	114.44	E	−2.2023	+1.7	1.1		216.7035			F.	F.
		W	−2.1990	−1.6						F.	F.
		Mean	−2.2006								
T. B. M. 109 and 109 *a*	115.42	E	+8.5013	−0.9	0.6		225.2039			F.	F.
		W	+8.4996	+0.8						F.	F.
		Mean	+8.5004								
T. B. M. 110 and 110 *a*	116.55	E	+2.1193	+0.5	0.3		227.3237			F.	J.
		W	+2.1202	−0.4						F.	J.
		Mean	+2.1198								
U. S. P. B. M. 74, Byron,		E	+1.0696	−0.2	0.1	8.5	228.3931	+1.2	228.3943	F.	F.
		E	+1.0692	+0.2						F.	J.
		Mean	+1.0694								
T. B. M. 111 and 111 *a*	117.75	E	−9.9868	+2.2	1.5		217.3391			F.	J.
		W	−9.9823	−2.3						F.	J.
		Mean	−9.9846								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	[illegible]	R	Elevation.	Rod correction.	Corrected elevation	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M*	*Mm.*	*M.*		
U. S. P. B. M. 75, on bridge over Rock River.	118.63	E ..	+0.0764	—1.5	1.0	......	217.4140	+0.8	217.4148	F.	F.
		W ..	+0.0734	+1 5	.....	......	... .	......	....	F.	F.
		Mean	+0.0749								
T. B. M. 112 and 112 *a*	119.26	E ..	+1 6651	—0.9	0.6	.....	219.0782	.....	....	F.	F.
		W	+1 6633	+0.9	......	......	....	......	....	F.	F.
		Mean .	+1.6642								
T. B. M. 113 and 113 *a*	121.00	E ..	+1 4311	+0.7	0.4	....	220.5100	......	....	F.	F.
		W ..	+1 4324	—0.6	......	......	....	......	....	F.	F.
		Mean .	+1.4318								
T. B. M. 115 and 115 *a*	122.75	E ..	—1 4952	—0.8	0.5	......	219.0140	.....	....	F.	J.
		W ..	—1.4967	+0.7	......	......	....	......	....	F.	J.
		Mean .	—1 4960								
T. B. M. 116 and 116 *a*	[illegible]	E ..	+1.7028	+1.4	1.0	.....	220.7180	......	....	F.	J.
		W ..	+1.7057	—1.5	...	......	....	......	....	F.	J.
		Mean	+1.7042								
* U. S. P. B. M. 76 Stillman Valley.	..	......	+0.7904	—0.2	0.1	[illegible]	221.5084	+1.0	221.5094	F.	F.
			+0.7901	+0.1	......	...	....	......	....	F.	J.
		Mean	+0.7902								
T B. M. 117 and 117 *a*	124.94	E ..	+2.7427	+0.9	0.9	....	222.4618	......	....	F.	F.
		W	+2.7473	—3.7	......	......	....	......	....	F.	F.
		E .	+2.7431	+0 5	......	......	....	......	....	F.	F.
		W .	+2.7412	+2.4	......	......	....	......	....	F.	F.
		Mean	+2.7436								
T B. M. 118 and 118 *a*	125.86	E	+7 5763†		0.5	......	231.0502	......	....	F.	J.
		W ...	+7 5867	+1.7	...	......	....	......	....	F.	J.
		E ...	+7 5904	—2.0	......	.....	....	......	....	F.	J.
		W	+7 5880	+0.4	....	.....	....	......	....	F.	J.
		E	+7 5883	+0.1	....	......	....	......	....	F.	J.
		Mean	+7 5884								
T B. M. 119 and 119 *a*	126.54	E .	+6.5616	—0.9	0.6	.....	237.6109	......	....		
		W	+6.5598	+0.9	....	......	....	......	....		
		Mean	+6.5607								
T. B. M. 120......	127.42	E ..	+ 6 6246	+1.2	1 1	......	244.2367	......	....	F.	F.
		W .	+ 6.6307	—4.9	.....	.....	....	......	....	F.	F.
		E .	+ 6.6230	+2.8	.. .	.....	....	......	....	[illegible]	F.
		W	+ 6.6250	+0.8	....	.....	....	......	....		
		Mean	+ 6.6258								
T B. M. 121 and 121 *a*	128.26	E ..	+ 6.8405	+0.6	0.4	...	251.0778	......	....	[illegible]	F.
		W	+ 6.8417	—0.6	.. ...	.....	....	......	....	F.	F.
		Mean .	+ 6.8411								
U. S. P. B. M. 77 ...	128.50	E	+ 1 4353	+0 4	0.1	9.0	252.5135	+1.9	252.5154	F.	F.
		W .	+ 1 4354	+0.3	....	.....	....	......	....	F.	F.
		E .	+ 1.4356	+0.1	.....	.....	....	......	....	F.	F.
		W .	+ 1 4363	—0.6	......	......	....	......	....	F.	F.
		Mean	+ 1.4357								

† Rejected.

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km		*M.*	*Mm.*	*Mm*	*Mm.*	*M*	*Mm.*	*M.*		
T. B. M. 122 and 122 *a*.	129. 65	E....	+ 2. 9136	−1. 0	1. 1	......	255. 4255	......	....	F	F.
		W ...	+ 2. 9104	+1. 6	......	......	......	......	....	F.	F.
		Mean	+ 2. 9120								
T. B. M. 124 and 124 *a*.	131. 14	E....	9. 3354	−0. 6	0. 4	......	246. 0895	......	....	F.	J.
		W ..	− 9. 3367	+0. 7	......	......	......	......	....	F	J
		Mean	− 9. 3360								
T. B. M. 125 and 125 *a*.	132. 24	E..	− 6. 0219	−0. 2	0. 1	......	240. 0674	......	....	F.	J.
		W	− 6. 0223	+0. 2	......	......	......	......	....	F.	J.
		Mean	− 6. 0221								
T. B. M. 126 and 126 *a*.	133. 78	E....	− 0. 9345	−0. 5	0. 3	......	239. 1324	......	....	F.	F
		W ...	− 0. 9355	+0. 5	......	......	......	......	....	F.	F.
		Mean	− 0. 9350								
T. B. M. 127 and 127 *a*.	134. 76	E ...	+ 2. 5593	+1. 5	1. 0	......	241. 6932	......	....	F.	F
		W	+ 2. 5624	−1. 6	......	......	......	......	....	F.	F.
		Mean	+ 2. 5608								
T. B. M. 128 and 128 *a*	135. 83	E....	− 0. 1398	+2. 4	1. 6	......	241. 5558	......	....	F.	J.
		W ...	− 0. 1351	−2. 3	......	......	......	......	....	F.	J.
		Mean	− 0. 1374								
T. B. M. 130 and 130 *a*.	138. 76	E. ..	+20. 0340	−1. 4	1. 0	......	261. 5884	......	....	F.	F.
		W	+20. 0311	+1. 5	......	......	......	......	....	F	F.
		Mean.	+20. 0326								
*U. S. P. B. M. 78, at Monroe, Ill.	......	......	+ 1. 4012	......	......	9. 3	262. 9896	+2. 2	262. 9918	F.	F
T. B. M. 133 and 133 *a*.	142. 07	E....	− 1. 0848	+2. 6	1. 9	......	260. 5064	......	....	F.	F.
		W ...	− 1. 0792	−2. 8	......	......	......	......	....	F.	F.
		Mean.	− 1. 0820								
T. B. M. 135 and 135 *a*.	144. 50	E....	−15. 9327	−1. 1	0. 7	......	244. 5726	......	....	F.	F.
		W	−15. 9348	+1. 0	......	......	......	......	....	F.	F.
		Mean	−15. 9338								
*U. S. P. B. M. 79, at Fielding, Ill.	......	......	+ 1. 0426	......	......	9. 5	245. 6152	+1. 7	245. 6169	F.	F.
T. B. M. 137 and 137 *a*.	146. 84	E.....	−0. 4699	+0. 5	0. 4	......	244. 1032	......	....	F	F.
		W ...	−0. 4688	−0. 6	......	......	......	......	....	F.	F.
		Mean.	−0. 4694								
T. B. M. 138 and 138 *a*.	148. 42	E	−8. 3335	+0. 1	0. 1	......	235. 7698	......	....	F.	F.
		W ...	−8. 3332	−0. 2	......	......	......	......	....	F.	F
		Mean	−8. 3334								
T. B. M. 139 and 139 *a*	149. 66	E ..	+2. 9648	+1. 5	1. 0	......	238. 7361	......	....	F.	A.
		W	+2. 9677	−1. 4	......	......	......	......	....	F.	A.
		Mean	+2. 9663								
T. B. M. 140 and 140 *a*	150. 46	E ...	+3. 5606	+0. 4	0. 3	......	242. 2971	......	....	F.	F.
		W	+3. 5614	−0. 4	......	......	......	......	....	F.	F.
		Mean.	+3. 5610								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	ε	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
T. B. M. 141 and 141 *a*	151.44	E	−3.2276	−3.4	0.8		239.0661			F.	A.
		W	−3.2335	+2.5						F.	A.
		E	−3.2309	−0.1						F.	A.
		W	−3.2320	+1.0						F.	A.
		Mean	−3.2310								
*U. S. P. B. M. 80, Kirkland.			+3.1488	−0.4	0.2	9.6	242.2145	+1.6	242.2161	F.	F.
			+3.1481	+0.3						F.	F.
		Mean	+3.1484								
T. B. M. 142 and 142 *a*	152.30	E	−0.1393	−1.9	1.3		238.9249			F.	A.
		W	−0.1431	+1.9						F.	A.
		Mean	−0.1412								
T. B. M. 143 and 143 *a*	153.46	E	+2.2405	+1.2	0.8		241.1666			F.	A.
		W	+2.2429	−1.2						[illegible]	A.
		Mean	+2.2417								
T. B. M. 145 and 145 *a*	155.90	E	+6.0062	−0.6	0.4		247.1723			F.	F.
		W	+6.0051	+0.5						[illegible]	F.
		Mean	+6.0056								
T. B. M. 147 and 147 *a*	158.26	E	+4.7315	+4.0	2.7		251.9077			F.	F.
		W	+4.7395	−4.0						F.	F.
		Mean	+4.7355								
T. B. M. 148 and 148 *a*	159.79	E	−3.0369	−0.3	0.2		248.8705			[illegible]	J.
		W	−3.0374	+0.2						F.	J.
		Mean	−3.0372								
*U. S. P. B. M. 81, Kingston.			+2.5376	−0.2	0.1	10.1	251.4079	+1.8	251.4097	F.	J.
			+2.5372	+0.2						F.	F.
		Mean	+2.5374								
T. B. M. 149 and 149 *a*	160.71	E	+4.6801	−1.9	1.2		253.5487			F.	J.
		W	+4.6764	+1.8						F.	J.
		Mean	+4.6782								
T. B. M. 151 and 151 *a*	163.08	E	−3.5879	+0.2	0.1		249.9610			F.	J.
		W	−3.5875	−0.2						F.	J.
		Mean	−3.5877								
T. B. M. 152 and 152 *a*	164.51	E	+8.5116	+1.0	0.7		258.4736			F.	F.
		W	+8.5137	−1.1						F.	F.
		Mean	+8.5126								
*U. S. P. B. M. 82, at Genoa, Ill.			+3.2111	−0.4	0.2	10.2	261.6843	+2.1	261.6864	F.	J.
			+3.2104	+0.3						F.	F.
		Mean	+3.2107								
T. B. M. 153 and 153 *a*	165.50	E	+1.6405	−0.7	0.5		260.1134			F.	F.
		W	+1.6391	+0.7						[illegible]	F.
		Mean	+1.6398								
T. B. M. 155 and 155 *a*	167.37	E	−0.7009	+7.5	1.9		259.4200			F.	[illegible]
		W	−0.6876	−5.8						F.	F.
		E	−0.6907	−2.7						F.	F.
		W	−0.6945	+1.1						F.	F.
		Mean	−0.6934								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
T. B. M. 157 and 157 a.	169. 72	E	+5. 4620	—1. 7	1. 1	......	264. 8808	......	....	F.	J.
		W	+5. 4588	+1. 7	......	......	....	......	....	F.	J.
		Mean	+5. 4603								
T. B. M. 158	170. 74	E	+3. 2858	+1. 3	2. 0	......	268. 1674	......	....	F.	J.
		W	+3. 2957	—8. 6	......	......	....	......	....	F.	J.
		E	+3. 2821	+5. 0	......	......	....	......	....	F.	J.
		W	+3. 2849	+2. 2	......	......	....	......	....	F.	J.
		Mean	+3. 2871								
T. B. M. 159 and 159 a.	171. 61	E	—4. 6466	+0. 8	1. 9	......	263. 5216	......	....	F.	J.
		W	—4. 6378	—8. 0	......	......	....	......	....	F.	J.
		E	—4. 6509	+5. 1	......	......	....	......	....	F.	J.
		W	—4. 6478	+2. 0	......	......	....	......	....	F	J.
		Mean	—4. 6458								
T. B. M. 161 and 161 a.	174. 33	E	+3. 0807	—0. 2	0. 1	......	266. 6021	......	....	F.	F.
		W	+3. 0803	+0. 2	......	......	....	......	....	F.	F.
		Mean	+3. 0805								
T. B. M. 162 and 162 a.	176. 23	E	+3. 5047	+1. 0	0. 7	......	270. 1078	......	....	F.	F.
		W	+3. 5067	—1. 0	......	......	....	......	....	F.	F.
		Mean	+3. 5057								
T. B. M. 164 and 164 a	178. 06	E	+7. 7493	—2. 7	1. 8	......	277. 8544	......	....	F.	F.
		W	+7 7439	+2. 7	......	......	....	......	....	F.	F.
		Mean	+7. 7466								
* U. S. P. B. M. 63, Hampshire, Ill	....	....	+2. 6225	+0. 1	0. 1	11. 0	280. 4770	+2. 7	280. 4797	F.	J.
			+2. 6228	—0. 2	----	......	....	......	....	F.	F.
		Mean	+2. 0226								
T. B. M. 165	178. 96	E	+5. 5515	+0. 9	0. 6	......	283. 4068	......	....	F.	J.
		W	+5. 5550	—2. 6	......	......	....	......	....	F.	J.
		E	+5. 5515	+0. 9	......	......	....	......	....	F.	J.
		W	+5. 5515	+0. 9	......	......	....	......	....	F.	J.
		Mean	+5. 5524								
T. B. M. 166 and 166 a.	180. 12	E	+ 6. 3176	+2. 6	1. 0	......	289. 7270	......	....	F.	J.
		W	+ 6. 3230	—2. 8	......	......	....	......	....	F.	J.
		E	+ 6. 3127	+7. 5	......	......	....	......	....	F.	J.
		W	+ 6. 3103	+0. 9	......	......	....	......	....	F	J.
		E	+ 6. 3200	+0. 2	......	......	....	......	....	F	J
		W	+ 6. 3263	—6. 1	......	......	....	......	....	F.	J.
		E	+ 6. 3195	+0. 7	......	......	....	......	....	F.	F.
		W	+ 6. 3235	—3. 3	......	......	....	......	....	F.	F.
		Mean	+ 6. 3202								
T. B. M. 167	180. 85	E	+ 6. 7413	+7. 2	1. 1	......	296. 4755	......	....	F.	J.
		W	+ 6. 7462	+2. 3	......	......	....	......	....	F.	J.
		E	+ 6. 7496	—1. 1	......	......	....	......	....	F.	J.
		W	+ 6. 7527	—4. 3	......	......	....	......	....	F.	J.
		E	+ 6. 7512	—2. 7	......	......	....	......	....	F.	J.
		W	+ 6. 7501	—1. 6	......	......	....	......	....	F	J.
		Mean	+ 6. 7485								
T. B. M. 168 and 168 a	181. 85	E	+ 6. 6583	+3. 5	1. 4	......	[redacted]	......	....	F.	J.
		W	+ 6. 6605	+1. 3	......	......	....	......	....	F.	J.
		E	+ 6. 6676	—5. 8	......	......	....	......	....	F.	J.
		W	+ 6. 6609	+0. 9	......	......	....	......	....	F.	J.
		Mean	+ 6. 6618								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		M.	Mm.	Mm.	Mm.	M.	Mm.	M.		
T. B. M. 197 and 197 *a*	213.30	E	+0.2547	−1.7	1.1		250.5351			F.	F.
		W	+0.2513	+1.7						F.	F.
		Mean	+0.2530								
T. B. M. 198 and 198 *a*	214.34	E	+3.2780	+1.3	0.9		253.8144			F.	F.
		W	+3.2807	−1.4						F.	F.
		Mean	+3.2793								
T. B. M. 199 and 199 *a*	215.10	E	−3.2312	−1.1	0.9		250.5821			F.	J.
		W	−3.2363	+4.0						F.	J.
		E	−3.2310	−1.3						F.	J.
		W	−3.2309	−1.4						F.	J.
		Mean	−3.2323								
T. B. M. 200	215.82	E	−2.8273	+1.4	0.9		247.7562			F.	F.
		W	−2.8245	−1.4						F.	J.
		Mean	−2.8259								
T. B. M. 201 and 201 *a*	217.03	E	+2.6177	−4.5	1.1	250.3	694			F.	F.
		W	+2.6120	+1.2						F.	F.
		E	+2.6102	+3.0						F.	F.
		W	+2.6129	+0.3						F.	F.
		Mean	+2.6132								
T. B. M. 203 and 203 *a*	218.62	E	−1.6997	+1.9	1.3	1.3	248.6716			F.	J.
		W	−1.6958	−2.0						F.	J.
		Mean	−1.6978								
T. B. M. 204 and 204 *a*	220.53	E	−7.5520	−0.3	0.2		241.1193			F.	J.
		W	−7.5525	+0.2						F.	J.
		Mean	−7.5523								
*U. S. P. B. M. 90 at Roselle, Ill.			+0.2886	0.0	0.0	12.4	241.4079	+1.5	241.4094	F.	F.
			+0.2885	+0.1						F.	F.
		Mean	+0.2886								
T. B. M. 206 and 206 *a*	222.63	E	−7.8993	−0.9	0.6		233.2191			F.	F.
		W	−7.9012	+1.0						F.	F.
		Mean	−7.9002								
T. B. M. 207 and 207 *a*	223.66	E	−3.8302	+2.3	1.5		229.3912			F.	J.
		W	−3.8256	−2.3							
		Mean	−3.8279								
T. B. M. 208 and 208 *a*	224.65	E	−0.7305	−0.3	0.2		228.6604			F.	F.
		W	−0.7311	+0.3						F.	F.
		Mean	−0.7308								
T. B. M. 209 and 209 *a*	226.30	E	−12.6975	−1.1	0.7		215.9618			F.	F.
		W	−12.6996	+1.0						F.	F.
		Mean	−12.6986								
*U. S. P. B. M. 91 at Itasca.			+3.1812	−0.3	0.2	12.6	219.1427	+0.9	219.1436	F.	F.
			+3.1806	+0.3						F.	F.
		Mean	+3.1809								
T. B. M. 210 and 210 *a*	227.22	E	−2.2257	+2.8	1.0		213.7389			F.	A.
		W	−2.2207	−2.2						F.	A.
		E	−2.2224	−0.5						F.	J.
		Mean	−2.2229								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M*		
T. B. M. 183 and 183 a.	197.06	E	—3.1127	+0.5	0.3	....	253.3150	.....	....	F	J
		W	—3.1117	—0.5	...	....	.....	....	......	F.	J.
		Mean	—3.1122								
T. B. M. 185 and 185 a.	199.20	E	—15.1930	—2.9	1.9	......	238.1191	...	.....	F.	F.
		W	—15.1988	+2.9	.....	...	......		....	F	F
		Mean	—15.1959								
T. B. M. 186 and 186 a.	201.02	E	—14.3749	+0.9	0.6	.....	223.7451	....	....	F.	F.
		W	—14.3732	—0.8	......	.....	....	......	....	F.	F.
		Mean	—14.3740								
*U. S. P. B. M. 86 W. Elgin, Ills.	....	......	+1.0002	.....	......	12.0	224.7453	+1.0	224.7463	....	J.
*U. S. P. B. M. 87 W., Elgin, Ills.	....	......	+0.3800	—0.2	0.1	12.0	224.1249	+1.0	224.1259	F.	J.
			+0.3796	+0.2	......	....	....	.....	....	F.	J.
		Mean	+0.3798								
*B. M. (for Mr. Newcombe) at Elgin, Ill.	....	....	+9.2756	......	......	....	233.4005	+1.3	233.4018	....	...
*Base of Rail C. M. & St. P. R. R., Bridge Street crossing.	....	....	—0.3540	....	.....	......	223.7709	....	....	....	J.
T. B. M. 188 and 188 a.	202.77	E	+1.0236	—1.0	0.6	......	224.7677	......	....	F.	J.
		W	+1.0217	+0.9	....	.	....	......	....	F.	J.
		Mean	+1.0226								
T. B. M. 189 and 189 a.	203.28	E	+1.3120	—0.9	0.6	......	226.0788	......	....	F.	J.
		W	+1.3102	+0.9	....	....	....	......	....	F.	J.
		Mean	+1.3111								
*U. S. P. B. M. 88 Bridge, Fox River.	....	....	—0.0010	—0.1	0.1	12.0	226.0777	+1.1	226.0788	F.	J.
			—0.0012	+0.1	.....	......	....	......	....	F.	J.
		Mean	—0.0011								
T. B. M. 191 and 191 a.	204.65	E	+2.3007	+0.2	0.1	......	228.3797	......	....	F.	J.
		W	+2.3011	—0.2	.....	....	....	......	....	F.	J.
		Mean	+2.3009								
T. B. M. 193 and 193 a.	206.83	E	+13.1758	—0.8	0.5	......	241.5547	......	....	F.	F.
		W	+13.1742	+0.8	......		....	......	....	F.	F.
		Mean	+13.1750								
T. B. M. 194 and 194 a.	208.46	E	+0.2088	—2.0	1.3	......	241.7615	.....	....	F.	F.
		W	+0.2049	+1.9	......	.....	....	......	....	F.	F.
		Mean	+0.2068								
T. B. M. 195 and 195 a.	210.25	E	+7.8912	—2.2	1.4	....	249.6505	......	....	F.	J.
		W	+7.8869	+2.1	......	.....	....	......	....	F.	J.
		Mean	+7.8890								
T. B. M. 196 and 196 a.	211.53	E	+0.6321	—0.5	0.3	......	250.2821	.....	....	F.	J.
		W	+0.6311	+0.5	...	......	....	......	....	F.	J.
		Mean	+0.6316								
*U. S. P. B. M. 89, Bartlett, Ill.	....	....	+0.8485	0.0	0.0	12.2	251.1306	+1.8	251.1324	F.	J.
			+0.8485	0.0	......	......	....	......	....	F.	F.
		Mean	+0.8485								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
T. B. M. 197 and 197 *a*	213.30	E	+0.2547	−1.7	1.1		250.5351			F.	F.
		W	+0.2513	+1.7						F.	F.
		Mean	+0.2530								
T. B. M. 198 and 198 *a*	214.34	E	+3.2780	+1.3	0.9		253.8144			F.	F.
		W	+3.2807	−1.4						F.	F.
		Mean	+3.2793								
T. B. M. 199 and 199 *a*	215.10	E	−3.2312	−1.1	0.9		250.5821			F.	J.
		W	−3.2363	+4.0						F.	J.
		E	−3.2310	−1.3						F.	J.
		W	−3.2309	−1.4						F.	J.
		Mean	−3.2323								
T. B. M. 200	215.82	E	−2.8273	+1.4	0.9		247.7562			F.	F.
		W	−2.8245	−1.4						F.	J.
		Mean	−2.8259								
T. B. M. 201 and 201 *a*	217.03	E	+2.6177	−4.5	1.1		250.3694			F.	F.
		W	+2.6120	+1.2						F.	F.
		E	+2.6102	+3.0						F.	F.
		W	+2.6129	+0.3						F.	F.
		Mean	+2.6132								
T. B. M. 203 and 203 *a*	218.62	E	−1.6997	+1.9	1.3	1.3	248.6716			F.	J.
		W	−1.6958	−2.0						F.	J.
		Mean	−1.6978								
T. B. M. 204 and 204 *a*	220.53	E	−7.5520	−0.3	0.2		241.1193			F.	J.
		W	−7.5525	+0.2						F.	J.
		Mean	−7.5523								
*U. S. P. B. M. 90 at Roselle, Ill.			+0.2886	0.0	0.0	12.4	241.4079	+1.5	241.4094	F.	F.
			+0.2885	+0.1						F.	F.
		Mean	+0.2886								
T. B. M. 206 and 206 *a*	222.63	E	−7.8993	−0.9	0.6		233.2191			F.	F.
		W	−7.9012	+1.0						F.	F.
		Mean	−7.9002								
T. B. M. 207 and 207 *a*	223.66	E	−3.8302	+2.3	1.5		229.3912			F.	J.
		W	−3.8256	−2.3							
		Mean	−3.8279								
T. B. M. 208 and 208 *a*	224.65	E	−0.7305	−0.3	0.2		228.6604			F.	F.
		W	−0.7311	+0.3						F.	F.
		Mean	−0.7308								
T. B. M. 209 and 209 *a*	226.30	E	−12.0975	−1.1	0.7		215.9618			F.	F.
		W	−12.0996	+1.0						F.	F.
		Mean	−12.0986								
*U. S. P. B. M. 91 at Itasca.			+3.1812	−0.3	0.2	12.6	219.1427	+0.9	219.1436	F.	F.
			+3.1806	+0.3						F.	F.
		Mean	+3.1809								
T. B. M. 210 and 210 *a*	227.22	E	−2.2257	+2.8	1.0		213.7380			F.	A.
		W	−2.2207	−2.2						F.	A.
		E	−2.2224	−0.5						F.	J.
		Mean	−2.2229								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
T. B. M. 211 and 211 *a*	228.14	E . . .	+ 0.0483	+0.3	0.2	......	214.6875	.....	....	F.	F.
		W . . .	+ 0.0469	—0.3	....	......	....	.....	....	F.	F.
		Mean	+ 0.0486								
T. B. M. 212 and 212 *a*	229.26	E....	+ 1.5918	—0.5	0.8	......	216.2788	.....	....	F.	F.
		W ...	+ 1.5908	+0.5	......	.....	....	.....	....	F.	F.
		Mean	+ 1.5913								
T. B. M. 213 and 213 *a*	230.89	E....	— 0.1205	—1.2	0.8	......	216.1571	....	....	F.	J.
		W ...	— 0.1228	+1.1	......	......	....	....	....	F.	J.
		Mean	— 0.1217								
T. B. M. 214..........	231.57	E....	— 4.3865	+3.2	2.1	....	211.7738	.....	....	F.	J.
		W ...	— 4.3824	—0.9	......	......	....	.....	....	F.	J.
		E....	— 4.3827	—0.6	......	......	....	.....	....	F.	J.
		W ...	— 4.3816	—1.7	......	......	....	.....	....	F.	F.
		Mean .	— 4.3833								
T. B. M. 215 and 215 *a*	232.41	E ...	+ 0.8893	+1.0	0.7	.....	212.6641	.....	....	F.	J.
		W ...	+ 0.8913	—1.0	......	......	....	.....	....	...	..
		Mean .	+ 0.8903								
*U. S. P. B. M. 92 at Bensenville, Ill.	.....	.....	+ 1.0094	0.0	0.0	12.8	213.6735	+0.7	213.6742	F.	J.
			+ 1.0093	+0.1	......	......	....	......	....	F.	F.
		Mean	+ 1.0094								
T. B. M. 216 and 216 *a*	234.08	E....	—4.7136	—0.5	0.4	....	207.9600	......	....	F.	F.
		W . .	—4.7146	+0.6	......	......	....	.....	.....	F.	F.
		Mean	—4.7141								
T. B. M. 218 and 218 *a*	235.83	E....	—4.2274	—1.5	1.0	.....	203.7211	......	....	F.	F.
		W	—4.2305	+1.6	.....	......	....	......	....	F.	F.
		Mean .	—4.2289								
T. B. M. 219 and 219 *a*	237.64	E.....	—0.7478	—1.6	1.1	......	202.9717	......	....	F.	J.
		W ...	—0.7510	+1.6	....	......	....	.....	....	...	...
		Mean	—0.7494								
*U. S. P. B. M. 93, at Mannheim, Ill.	....	....	+1.5343	+0.4	0.2	12.9	204.5064	+0.5	204.5060	F.	J.
			+1.5350	—0.3	......	......	....	....	....	F.	F.
		Mean .	+1.5347								
T. B. M. 220 and 220 *a*	238.59	E.....	—0.9666	—0.7	0.5	......	202.0044	......	....	F.	J.
		W ...	—0.9681	+0.8	.....	......	....	......	....	..	...
		Mean .	—0.9673								
T. B. M. 221 and 221 *a*	239.42	E	—0.6870	—0.9	0.6	......	201.3165	......	....	F.	F.
		W ...	—0.6886	+0.9	......	......	....	......	....	F.	F.
		Mean .	—0.6879								
T. B. M. 223 and 223 *a*	241.96	E.....	—3.2529	—2.3	1.6	......	198.0613	......	....	F.	F.
		W	—3.2576	+2.4	......	......	....	......	....	F.	F.
		Mean	—3.2552								
T. B. M. 225 and 225 *a*	244.05	E.....	+4.2453	+2.6	1.8	......	202.3092	......	....	F.	J.
		W	+4.2506	—2.7	......	......	....	......	....	F.	J.
		Mean .	+4.2479								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
T. B. M. 226 and 226 *a*	245. 35	E	+2. 3476	+0. 6	0. 4		204. 6574			F.	F.
		W	+2. 3488	-0. 6						F.	F.
		Mean	+2. 3482								
T. B. M. 227 and 227 *a*	246. 32	E	-1. 5306	+0. 2	0. 2		203. 1270			F.	F.
		W	-1. 5301	-0. 3						F.	F.
		Mean	-1. 5304								
T. B. M. 229 and 229 *a*	248. 38	E	-8. 7232	+1. 6	1. 0		194. 4054			F.	F.
		W	-8. 7201	-1. 5						F.	F.
		Mean	-8. 7216								
T. B. M. 230 and 230 *a*	249. 10	E	-1. 2603	+2. 1	0. 6		193. 1472			F.	F.
		W	-1. 2560	-2. 2						F	F.
		E	-1. 2590	+0. 8						F.	F.
		W	-1. 2575	-0. 7						F.	F.
		Mean	-1. 2582								
*U. S. P. B. M. 94, at Cragin.			+1. 2989	-0. 2	0. 1	13. 2	194. 4459	+0. 2	194. 4461	F.	F.
			+1. 2985	+0. 2						F.	F.
		Mean	+1. 2987								
T. B. M. 231 and 231 *a*	250. 06	E	-1. 6839	+0. 7	0. 4		191. 4640			F.	F.
		W	-1. 6826	-0. 6						F.	F.
		Mean	-1. 6832								
T. B. M. 232 and 232 *a*	251. 31	E	-0. 9968	+1. 4	0. 9		190. 4658			F.	F.
		W	-0. 9996	-1. 4							
		Mean	-0. 9982								
T. B. M. 233 and 233 *a*	352. 50	E	-1. 3649	-2. 5	1. 7		189. 0984			F.	J.
		W	-1. 3699	+2. 5						F.	J.
		Mean	-1. 3674								
T. B. M. 234 and 834 *a*	254. 27	E	-1. 4166	+2. 6	1. 6		187. 6844			F.	J.
		W	-1. 4081	-5. 9						F.	J.
		E	-1. 4126	-1. 4						F.	J.
		W	-1. 4185	+4. 5						F.	J.
		Mean	-1. 4140								
T. B. M. 236 and 236 *a*	256. 11	E	-2. 3264	+0. 6	0. 4		185. 3586			F.	F.
		W	-2. 3252	-0. 6						F.	F.
		Mean	-2. 3258								
*U. S. P. B. M. 95 at Chicago.			+1. 0850	0. 0	0. 0	13. 5	186. 4436	-0. 1	186. 4435	F.	F.
			+1. 0849	+0. 1						F.	F.
		Mean	+1. 0850								
T. B. M. 237 and 237 *a*	257. 77	E	-0. 2334	+1. 0	0. 7		185. 1262			F.	F.
		W	-0. 2314	-1. 0						F.	F.
		Mean	-0. 2324								
*Chicago City B. M. I.			+2. 4761			13. 5	187. 6023	0. 0	187. 6023	F.	
T. B. M. 238	258. 57	E	+0. 3878	-0. 7	0. 4		185. 5128			F.	
		W	+0. 3860	+0. 6						F.	
		Mean	+0. 3866								

***Results of precise leveling, Fulton to Chicago, Ill.*—Continued.**

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
*Chicago City B. M. II			+1.6024	−0.4	0.8	13.5	187.1148	0.0	187.1148		F.
			+1.6016	+0.4							F.
		Mean	+1.6020								
T. B. M. 239 and 239 a	258.97	E	−0.1588	−0.7	0.5		185.3533			F.	F.
		W	−0.1602	+0.7						F.	F.
		Mean	−0.1595								
*Chicago City B. M. IV.	259.63	E	+1.6798	+2.4	1.0	13.5	187.0355	0.0	187.0355	F.	J.
		W	+1.6802	−4.0						F.	J.
		E	+1.6823	−0.1						F.	J.
		W	+1.6806	+1.6						F.	J.
		Mean	+1.6822								
*Chicago City B. M. III		E	−1.1830	+0.2	0.1	13.5	185.8527	−0.1	185.8526	F.	J.
		W	−1.1827	−0.1						F.	J.
		Mean	−1.1828								
*Zero of Chicago ave. River gauge			−3.0260			13.5	182.8267	−0.2	182.8265	F	J.
*Zero of temporary gauge A.			−3.0595			13.5	182.7932	−0.2	182.7930	F.	J.
T. B. M. 240	260.46	E	+0.1820	−1.2	0.8		187.2163			F.	F.
		W	+0.1797	+1.1						F.	J.
		Mean	+0.1808								
*Chicago City B. M. VI.			+0.2785	−0.1	0.1	13.6	187.4947	0.0	187.4947		F.
			+0.2783	+0.1							F.
		Mean	+0.2784								
*U. S. P. B. M. 96, at Chicago.			+1.2216	+0.1	0.0	13.6	188.4379	0.0	188.4379		F.
			+1.2216	0.0							F.
		Mean	+1.2216								
T. B. M. 241	260.88	E	−0.3157	−1.1	0.7		186.8996			F.	F.
		W	−0.3178	+1.0						F.	J.
		Mean	−0.3168								
Chicago City B. M. IX.	261.20	E	+0.0580	−0.8	0.6	13.6	186.9567	0.0	186.9567	F.	F.
		W	+0.0563	+0.9						F.	J.
		Mean	+0.0572								
*U. S. P. B. M. 97, at Chicago.			+0.7092	+0.2	0.2	13.6	187.6661	0.0	187.6661	F.	F.
			+0.7097	−0.3						F.	F.
		Mean	+0.7094								
*U. S. P. B. M. 98, at Chicago.			+1.5330	−0.1	0.1	13.6	188.4896	0.0	188.4896	F.	F.
			+1.5328	+0.1						F.	F.
		Mean	+1.5329								
*Chicago City B. M. VIII.			−0.1007	−0.1	0.1	13.6	186.8559	0.0	186.8559	F.	F.
			−0.1010	+0.2						F.	F.
		Mean	−0.1008								
*Zero of temporary gauge "B."	261.36	E	−3.9299	−0.1	0.1	13.6	183.0267	−0.2	183.0265	F.	F.
		W	−3.9302	+0.2							
		Mean	−3.9300								

Results of precise leveling, Fulton to Chicago, Ill.—Continued.

Bench.	Distance.	Direction.	Difference of elevation.	V	r	R	Elevation.	Rod correction.	Corrected elevation.	Supports.	Observer.
	Km.		*M.*	*Mm.*	*Mm.*	*Mm.*	*M.*	*Mm.*	*M.*		
*Chicago City B. M. VII.	......	......	+0.7220	+0.2	0.1	13.6	187.6217	0.0	187.6217	F.	F.
			+0.7223	−0.1	.....	......	....	.....	....	F.	F
		Mean.	+0.7222								
*U. S. P. B. M. 99, at Chicago.	....	.....	−1.2548	+0.5	0.3	13.6	186.3674	−0.1	186.3673	F.	F.
			−1.2538	−0.5	.....	......	....	.....	....	F.	J.
		Mean.	−1.2543								
*T. B. M. 242	.....	.....	−3.0020	+0.6	0.4	13.6	184.6203	.....	....	F.	F.
			−3.0008	−0.6	.....	.....	....	.....	....	F.	J.
		Mean.	−3.0014								
*Zero of temporary gauge "C."	.....	....	−4.5045	+1.4	0.9	13.6	183.1186	−0.2	183.1184	F.	F.
			−4.5017	−1.4	....	.....	....	.....	....	F.	J.
		Mean	−4.5031								
*Zero of U. S. E. self-registering gauge at Harbor Improvement Office.		.....	−4.5037	+0.9	0.6	13.6	183.1189	−0.2	[illegible]	F.	F.
			−4.5019	−0.9	...	....	....	.....	....	F.	J.
		Mean	−4.5028								
*T. B. M. 243		E ...	−0.3055	+1.4	0.5	13.6	184.3163	.....	....	F.	F.
		W ...	−0.3040	−0.1		.....	....	.....	....	F.	F.
		E ...	−0.3027	−1.4	.....	.....	....	.....	....	F.	J.
		Mean	−0.3041								
*U. S. E. XIII on light-house.	....	....	+1.3220	−3.6	2.4	13.8	185.6346	−0.1	185.6345	...	F.
			+1.3148	+3.6	......	....	....	.....	....	...	J.
		Mean.	+1.3164								
*U. S. E. XI on breakwater.	....	..	+0.9693	−5.7	3.8	14.1	185.2798	−0.1	185.2797		F.
			+0.9579	+5.7	......	....	....	.....	....		J.
		Mean	+0.9636								
*U. S. E. XII on breakwater.	....	.....	+1.1437	−5.9	4.0	14.2	185.4540	−0.1	185.4539		F.
			+1.1318	+6.0	......	......	....	.....	....		J.
		Mean	+1.1378								
Zero of outer crib gauge (temporary).	.....	.....	....	.....	0.3	13.6	182.8287	0.0	....		
Zero of well or crib gauge.	..		+2.4380	−0.2	0.1	13.6	185.2665	−0.1	185.2664		J.
			+2.4377	+0.1	..	...	....	.....	....		
		Mean	+2.4378								
City directrix	.	....	−2.4414	..	.	13.6	182.8251	−0.1	182.8250		J.
U. S. P. B. M. 100.	.....	....	+2.4461	......	....	13.4	185.2712	−0.1	185.2712		J.

DESCRIPTION OF PERMANENT BENCH-MARKS BETWEEN FULTON AND CHICAGO, ILL.

(All permanent bench-marks are lettered U. S. P. B. M. For description of U. [illegible] P. B. M's 53, 54, 55, and 56, see Annual Report for 1883, page 141.)

U. S. P. B. M. 57 is at Fulton, Whitesides County, Illinois, on the northeast co[illegible] of Cherry and Bench streets. It [illegible] center mark of copper bolt leaded horizontall[illegible] in south face of stone foundation wall to the Northern Illinois College, 3¼ feet above the ground, and 14 inches from the southwest corner of foundation. Elevation, $188^{m}.1[illegible]76$.

U. S. P. B. M. 58 is in Whitesides County Illinois, on the southeast abutment of the railroad bridge north of Fulton Junction, 970 meters north from crossing of C., M. and St. P. and the C. and N. W. R. R., first being the top of a copper bolt leaded vertically in the bridge-seat stone. Elevation, $183^{m}.7503$.

B. M. 35, of Captain Mackenzie, at Fulton, on water table, southeast corner of engine-room of elevator, under planking. Elevation, 184m.7790.

U. S. P. B. M. 59, three miles north of Fulton Junction, in Whitesides County, Illinois, in west end of north abutment of railroad bridge, being the top of copper bolt leaded vertically in second course of stone from top. Elevation, 185m.8275.

U. S. P. B. M. 60, at Thomson, Carroll County, Illinois, west end of Christian church, 250 meters east of C., M. and St. P. R. R., being the center mark of copper bolt leaded horizontally in the foundation wall. Elevation, 190m.8597.

U. S. P. B. M. 61, one mile south of Savanna, Carroll County, Illinois, in middle pier and directly under railroad bridge No. E 392, being top of copper bolt leaded vertically. Elevation, 185m.0035.

U. S. P. B. M. 62, at Savanna, Carroll County, Illinois, on door-sill of engine-room of the C., M. and St. P. R. R. Co.'s elevator on the bank of the river, being top of copper bolt leaded vertically in the south end of the south door east side. Elevation, 186m.5778.

Captain Mackenzie's B. M. 34 is on the same sill marked "+." Elevation, 186m.5788.

U S. P. B. M. 63, at Savanna, Carroll County, Illinois, on northwest corner of Main and Jefferson streets, in facing stone, south face, southeast corner of brick building owned by W. B. Laws, being the center of copper bolt leaded horizontally. Elevation, 188m.8537.

U. S. P. B. M. 64, Savanna, Carroll County, Illinois, 2¼ miles east of the "Junction House," and 50 meters south of the main line of the C., M. and St. P. R. R., in the top of west end of north abutment of wagon bridge over Plum River, being the top of copper bolt leaded vertically. Elevation, 187m.0846.

U. S. P. B. M. 65, 300 meters north of "1 mile post," west of Hickory Grove Station, C., M. and St. P. R. R., Carroll County, Illinois, in east side of stone foundation wall of barn owned by J. Fish, being the center mark of copper bolt leaded horizontally, 5 feet south of door and 3 feet above ground. Elevation, 211m.5027.

U. S. P. B. M. 66, at Mount Carroll, Carroll County, Illinois, about 100 meters south of depot and 40 meters east of C., M. & St. P. R. R., in barn building attached to elevator, being the center mark of copper bolt leaded horizontally in the west end of south face of stone foundation, 3 feet above the ground. Elevation, 255m.1128.

U. S. P. B. M. 67, about 4 miles west of Lanark, Carroll County, Illinois, north end of east abutment of railroad bridge No. 454 (C., M. and St. P. R. R.), over Carroll Creek, being the top of copper bolt leaded vertically in the second course of stone from the top. In the stone are cut the letters "U. S. P. B. M.," and the date, "May 25, 1883." Elevation, 246m.5122.

U. S. P. B. M. 68, at Lanark, Carroll County, Illinois, 25 feet from the southwest corner of Carroll and Main streets on the upper doorstep of brick building occupied by a bank and owned by Walff Bros., being the top of copper bolt leaded vertically in upper doorstep on Carroll street, and 1½ feet above ground. Elevation, 275m.2841.

U. S. P. B. M. 69, is 2¼ miles east of Lanark, Carroll County, Illinois, on the line of the C., M. and St. P. R. R., in coping of north end of east abutment of railroad bridge over Carroll Creek, being the top of a copper bolt leaded vertically. Elevation, 262m.1845.

U. S. P. B. M. 70 is 3¼ miles east of Lanark Junction, Carroll County, Illinois, on the line of the C., M. & St. P. R. R., 140 meters south of the track, in barn building owned by Mr. M. Crabtree, being the center mark of copper bolt leaded horizontally in the east end of the north face of stone foundation wall, 2 feet above the ground. Elevation, 294m.8395.

U. S. P. B. M. 71, at Foreston Junction, Ogle County, Illinois, where the C., M. & St. P. R. R. passes under the Illinois Central, in the lower step of west wing of south abutment of the stone archway in the fourth course of stone from the bottom, being the top of a copper bolt leaded vertically. Elevation, 273m.3979.

U. S. P. B. M. 72, at Adeline Station, C., M. & St. P. R. R., Ogle County, Illinois, in elevator building of the aforesaid railroad company, being the center mark of copper bolt leaded horizontally in the east face of stone foundation wall at the southeast corner, about 4 feet above the ground. Elevation, 234m.9307.

U. S. P. B. M. 73, at Leaf River, Ogle County, Illinois, 70 meters east of the depot and just opposite the water-tank, in elevator building owned by D. Sprecker, being the center mark of copper bolt leaded horizontally in the east end of south face of the stone foundation wall about 4 feet above the ground. Elevation, 222m.1946.

U. S. P. B. M. 74, at Byron, Ogle County, Illinois, 560 meters south of the C., M. & St. P. R. R. track measured on Walnut street, in brick and stone building fronting on said street, and occupied by hardware and dry-goods stores, and the Commercial Hotel, owned by J. F. Spalding, being center mark in copper bolt leaded horizontally in north wall of northeast corner, 11 inches from corner and 4 feet above ground. Elevation, 228m.3943.

U. S. P. B. M. 75 is 1¼ miles east of Byron, Ogle County, Illinois, on the line of the C., M. & St. P. R. R. track, in west abutment of railroad bridge over Rock River, being

the top of copper bolt leaded vertically in stone coping south side. Elevation, $217^m.4148$.

U. S. P. B. M. 76, at Stillman Valley, Ogle County, Illinois, 50 meters east of the depot and 20 meters south of the main track of the C., M. & St. P. R. R. Co., in the west front of foundation wall of the elevator building owned by J. D. & J. J. White, being the center mark of copper bolt leaded horizontally, 11 inches from the northwest corner. Elevation, $221^m.5094$.

U. S. P. B. M. 77 is 2,600 meters west of Davis Junction, all in Ogle County, Illinois, in north end of west abutment of small bridge of the C., M. & St. P. R. R., being the top of a copper bolt leaded vertically in the coping stone. Elevation, $252^m.5154$.

U. S. P. B. M. 78, at Monroe, Ogle County, Illinois, 24 meters west of depot of the C., M. & St. P. R. R., in east face of stone foundation wall of elevator building, owned by D. A. Cipperly, being the center mark of copper bolt leaded horizontally, 1½ feet north of southeast corner and 3½ feet above the ground. Elevation, $262^m.9918$.

U. S. P. B. M. 79 at Fielding, De Kalb County, Illinois, 10 meters north of main track of the C., M. & St. P. R. R., in south face of stone foundation wall of elevator, being center mark of copper bolt leaded horizontally, 25 feet west of the southeast corner and 2½ feet above the ground. Elevation, $245.^m6169$.

U. S. P. B. M. 80, at Kirkland, De Kalb County, Illinois, 175 meters south of railroad track, on street running to depot from the south, in brick building owned by Dean & Rowen, to be used when completed for a bank, being the center of a copper bolt leaded horizontally, 6 inches from the northwest corner, on the west face of stone foundation 5 feet above the ground. Elevation, $242^m.2161$.

U. S. P. B. M. 81, at Kingston, De Kalb County, Illinois, ½ mile east of the depot and 10 meters north of the main track, in a brick store building in Chapman's addition belonging to Mr. Julius Chapman, being center mark in copper bolt leaded horizontally in the water table on west face, northwest corner. Elevation, $251^m.4097$.

U. S. P. B. M. 82, at Genoa, De Kalb County, Illinois, 100 meters south of main track of the C., M. & St. P. R. R., at the corner of Main and Emmett streets in brick store building owned by Alexander Crawford, being the top of a copper bolt leaded vertically in the south end of stone door sill on the east side. Elevation, $261^m.6864$.

U. S. P. B. M. 83, at Hampshire, Kane County, Illinois, on State street, in brick building owned by Phillip Shultz, and used for post-office and drug store, in the stone water table in the west face of the southwest corner, being the center mark of copper bolt leaded horizontally. Elevation, $280^m.4797$.

U. S. P. B. M., 84 at Pingree Grove, Kane County, Illinois, about 100 meters northeast of depot, in foundation of store building owned by J. B. Schedden, in north face 5 feet from the northwest corner, 1 foot above the ground, being the center mark of a copper bolt leaded horizontally. Elevation, $285^m.8096$.

U. S. P. B. M. 85 is ¾ of a mile west of Dunser Station, Kane County, Illinois, on the line of the C., M. & St. P. R. R., in railroad culvert No. 19, 20 meters north of railroad track, being the top of a copper bolt leaded vertically in coping stone in east end of north abutment. Elevation, $265^m.3564$.

U. S. P. B. M. 86, at West Elgin, Kane County, Illinois, corner of State street and Highland avenue, in water table of the large brick building known as the Waverly House, on north face, 6 inches from the northeast corner and 4 feet above the ground, being center mark of a horizontal bolt. Elevation, $224^m.7463$.

U. S. P. B. M. 87, at West Elgin, Kane County, Illinois, on the southwest corner of River street and the C., M. & St. P. R. R. track, on the north face of brick and stone business building owned by Robert Beckwith, being the top of copper bolt leaded vertically in east end of stone doorstep. Elevation, $224^m.1259$.

B. M. "Newcomb," at East Elgin, Ill., on Center street, btween Du Page and Chicago streets, being cross (X) cut in west face of brick foundation wall of building owned by the Elgin Scientific Association. Elevation, $233^m.4018$.

U. S. P. B. M. 88 is 1½ miles south of Elgin, Kane County, Illinois, in west end of south abutment of the C., M. & St. P. R. R. bridge over Fox River, being the top of a copper bolt leaded vertically in the coping stone. Elevation, $226^m.0788$.

U. S. P. B. M. 89, at Bartlett, Cook County, Illinois, 150 meters northwest of depot and 100 meters north of railroad track of the C., M. & St. P. Co., in the stone foundation of the Congregational Church, being the center mark of copper bolt leaded horizontally on the east face of the southeast corner. Elevation, $251^m.1324$.

U. S. P. B. M. 90, at Roselle, Du Page County, Illinois, on the southeast corner of Chicago street and road crossing it, in the north face of foundation wall of brick business building owned by Mathew Secker, standing about 80 meters north of railroad track, being the center of copper bolt leaded horizontally, 3 feet from the northeast corner and 2 feet above the ground. Elevation, $241^m.4094$.

U. S. P. B. M. 91, at Itasca, Du Page County, Illinois, 80 meters north of track of the C., M. & St. P. R. R., and in a northeasterly direction from the depot, in the foundation wall of frame store building (east face), owned by Dr. Elijah Smith, being the

center of copper bolt leaded horizontally, 2 feet from the southeast corner. Elevation, 219m.1436.

U. S. P. B. M. 92, at Bensenville, Du Page County, Illinois, 40 meters north of depot, in south side of frame store building, owned by C. A. Franz, being the center of copper bolt leaded horizontally in the stone foundation, one foot west of the southeast corner and 2 feet above ground. Elevation, 213m.6742.

U. S. P. B. M. 93, at Mannheim, Cook County, Illinois, 250 meters northwest of the depot of the C., M. & St. P. R. R., in the south side of the base of the brick chimney at Mr. C. H. Bossenberg's creamery, being the center mark of copper bolt leaded horizontally in the middle of the chimney and 3 feet above the ground. Elevation, 204m.5069.

U. S. P. B. M. 94, at Cragin, Cook County, Illinois, on the northeast corner of Grand and Armitage avenues, about 150 meters north of the line of the C., M. & St. P. R. R., in the east face of foundation wall of Jennings's brick saloon building, being the center mark of copper bolt leaded horizontally, 10 inches from the southeast corner and 4 feet above the ground. Elevation, 194m.4461.

U. S. P. B. M. 95, at Chicago, Ill., on the southeast corner of Dixon street and Bloomingdale road about 20 meters southwest of crossing of the C., M. & St. P., and C. & N. W. R. R., in the west face of brick building known as L. Epps & Co.'s malt house, 6 inches from the northwest corner and 2½ feet above the ground, being the center of a copper bolt leaded horizontally. Elevation, 186m.4435.

U. S. P. B. M. 96, at Chicago, Ill., on the south side of Chicago avenue at Nos. 242 and 244, near Clark street, in police station brick building, in the north face 1 foot west of the northeast corner and 3½ feet above the ground, being the center mark of a copper bolt leaded horizontally. Elevation, 188m.4379.

U. S. P. B. M. 97, at Chicago, Ill., on the northeast corner of Chicago avenue and Pine street, in the east face of the southeast buttress of stone engine-house of the Chicago Water Works, in the stone water-table 18 inches north of the southeast corner and 3 feet above the ground. Elevation, 187m.6661.

U. S. P. B. M. 98, at Chicago, Ill., on the northwest corner of Chicago avenue and Pine street, in middle of the south wall of water tower, in the east end of the south doorsill, 3 feet above the ground, being the top of a copper bolt leaded vertically. Elevation, 188m.4896.

U. S. P. B. M. 99, at Chicago, Ill., in Illinois Central Railroad stone freight depot, situated on Goodrich street docks on the west side of slip A, opposite the Central Elevator, in east face of foundation wall 1 foot south of the northeast corner and 2½ feet above the ground, being the center mark of a copper bolt leaded horizontally. Elevation, 186m.3673.

U. S. P. B. M. 100, in Lake Michigan, on the crib of the Chicago Water Works, on the top of the iron cylinder of shaft of the 5-foot tunnel, nearly of same elevation as the zero of the gauge, on the east side of the top of the shaft, being a cross (×) cut with cold chisel, not lettered.

DESCRIPTIONS AND ELEVATIONS OF CHICAGO CITY BENCH-MARKS.

The city directrix is 8.01 feet below the zero of the crib-gauge, which reads downwards from the top or zero. Elevation, 182m.8250.

B. M. I is top of east end of stone step of private entrance to No. 161 North avenue, on the northwest corner of Halsted street and North avenue. Elevation, 187m.6023.

B. M. II is stone step west corner of brick house No. 153 Division street, being the third lot west of Grace street. Elevation, 187m.1148.

B. M. III, water table of round-house, northeast corner of Halsted and West Chicago avenue, established before "the fire." Elevation, 185m.8526.

B. M. IV, extreme corner of stone sidewalk at the northeast corner of Wesson street and East Chicago avenue. Elevation, 187m.0355.

B. M. VI, east end of coping of iron fence of police station on the south side of Chicago avenue near Clark street. Elevation, 187m.4947.

B. M. VII, on corner of stone water-table northwest corner of tower of St. James Church, at southeast corner of Cass and Huron streets. Elevation, 187m.6217.

B. M. VIII, corner of stone water-table, southeast corner of Chicago Water Works (machine shop), east of Pine street on Chicago avenue. Elevation, 186m.8559.

B. M. IX, north corner of iron frame of manhole to Chicago avenue shaft at Water Works into 7-foot tunnel, said to have been disturbed by grading sidewalk. Elevation, 186m.9567.

DESCRIPTIONS AND ELEVATIONS OF UNITED STATES ENGINEERS, BENCH-MARKS AT CHICAGO, ILL., SET FROM THE CITY BENCH-MARK VII. DESCRIPTIONS TAKEN FROM RECORDS IN THE OFFICE OF MAJOR W. H. H. BENYAURD, CORPS OF ENGINEERS.

B. M. XI, top of spike on United States easterly breakwater in center of long timber and 6 inches south of second cross-tie, counting from inner corner of breakwater. Elevation, 185m.2797.

B. M. XII, top of water-gauge chamber, middle of south wall of box. Same as read in 1876–'79. Elevation, $185^{m}.4539$.

B. M. XIII, upper surface of lower horizontal bar (compression member) between the southerly pillars of light-house on the north side of the mouth of Chicago River. Elevation $185^{m}.6345$.

DESCRIPTION OF PERMANENT BENCH-MARKS OF COAST AND GEODETIC SURVEY ON MISSISSIPPI RIVER FROM GREENVILLE, MISSISSIPPI, TO CARROLLTON, LOUISIANA.

B. M. 1 is on the corrugated iron door-sill of a brick building in Greenville, known as the bank building. It is said to be one of the oldest brick buildings in town; the Levee Board has its rooms in this building, over the bank. The exact point is near the back side and west end of sill, 320 millimeters from front face, 55 millimeters from door-strip, 90 millimeters from right-hand (west) door jamb. The door is near the northwest corner of building, in north side. The point is not marked. Elevation, $46^{m}.0891$.

B. M. 2 is center of head of copper bolt 10 centimeters long and 2 centimeters diameter, leaded horizontally into a brick in the fourteenth tier of bricks above the water-sill of the large chimney of C. B. Huntingdon's gin-house near Greenville, Miss. It is on the side of the chimney facing the river. The gin-house stands about half a mile below the town and as far from the river bank. The chimney is said to be the oldest one erected for its purpose in Washington County. The letters U. S. ⊙ B. M. are cut in the brick, as here shown. Elevation, $46^{m}.5836$.

B. M. 11 is top of copper bolt in top of cement post 3 feet long, set with top flush with surface of ground in yard of Mr. Warfield on Highland Plantation, Warfield Point, Washington County, Mississippi. The cement post is north of the house, between the line of the fence and a cottonwood tree about 4 feet in diameter, and is eight feet from the tree. Elevation, $45^{m}.5590$.

B. M. 19 is the center of head of a copper bolt about 2 centimeters in diameter leaded horizontally into the brick chimney of the gin-house of Refuge Plantation. The chimney is cylindrical and stands about 1 mile north of Refuge Landing and about ¼ mile back from the chute of Island 84. The bolt is about 3 feet above ground. Elevation, $46^{m}.0042$.

B. M. 22 is the center of head of a copper bolt about 2 centimeters in diameter leaded into the brick foundation of Mr. Richardson's store at Refuge, Mississippi. The bolt is in the twenty-first tier of bricks above the water sill of the second pier from the levee on the northwest side of the building. Elevation, $45^{m}.7483$.

B. M. 33 is the center of head of a copper bolt 2 centimeters in diameter leaded horizontally into the brick foundation on the front side of the dwelling of Wayside Plantation, near the banks of Lake Lee, Washington County, Mississippi. It is in the fourth tier of brick below the wood sill and in the eighth tier above the ground. It is $0^{m}.35$ south from the south end of the porch and $0^{m}.64$ from the north end of a small ventilator covered with iron grating. Elevation, $43^{m}.1845$.

B. M. 39 is the center of head of a copper bolt 2 centimeters in diameter leaded horizontally into the north face of the large brick chimney of gin-house on Buckner's estate, Auburn Plantation, Washington County, Mississippi. The letters U. S. B. M. are cut in the surrounding bricks. The chimney stands about 1.5 kilometers south of the levee running along Lake Lee. Elevation, $42^{m}.3212$.

B. M. 42 is the center of head of a copper bolt leaded horizontally into the large brick chimney of gin-house of Glenora Plantation, Washington County, Mississippi. The gin-house stands about a kilometer back of the levee. The letters U. S. B. M. are cut in the surrounding bricks. Elevation, $42^{m}.8024$.

B. M. 46 is the center of head of a copper bolt 2 centimeters in diameter leaded horizontally into the west face of the gin-house chimney of Mr. Merit Williams on Longwood Plantation, Washington County, Mississippi. The chimney stands about 270 meters back from the levee and about 700 meters from the river. The bench-mark is in the middle of the thirteenth brick above water-sill and fourth brick from southwest corner of chimney. Elevation, $42^{m}.7002$.

B. M. 56 is the top of a copper bolt 2 centimeters in diameter and 20 centimeters long placed vertically in a cement post set in ground 100 feet east of road leading from Lake Washington Landing to Lake Washington and 53 feet south of levee. It is on the plantation owned by D. M. Hill. Elevation, $42^{m}.0971$.

B. M. 62 is the center of head of copper bolt 2 centimeters in diameter and 7 centimeters long, leaded horizontally into the brick underpinning of dwelling house of W. W. Worthington, jr., just back of Leota on the Maryland Plantation, Washington County, Mississippi. The house is about 250 meters from the levee. The bolt is in center of second brick below wood-sill and sixth brick west of small ventilator. Elevation. $42^{m}.7541$.

B. M. 65 is center of head of a copper bolt leaded horizontally into a brick in front side of dwelling-house on Albemarle Plantation, Washington County, Mississippi, owned by Mr. H. J. Johnson. It is in the second brick below water-sill, and about the middle of the large brick column on the left-hand side of the entrance to the house. The house is about 1 mile below Leota and about 150 meters from the river. Elevation, 42^m.9107.

B. M. 70 is the center of head of a copper bolt leaded horizontally into the brick pillar at the northwest corner of the dwelling house on Palmetto Plantation, owned by F. G. Kershaw, in Washington County, Mississippi. Elevation, 40^m.9311.

B. M. 83 is the center of head of a copper bolt leaded horizontally into second brick pillar north from main entrance of dwelling-house owned by Mr. Robert Turnbull, on Riverdale Plantation, in Issaquena County, Mississippi. It is in third tier of bricks below the weatherboarding. Elevation, 40^m.6765.

B. M. 90 is the center of head of a copper bolt leaded horizontally into the front face of the brick pillar that supports the southwest corner of the portico of Col. H. B. Keep's house on Glen Annie Plantation, about 2 miles above Mayersville, in Issaquena County, Mississippi. Elevation, 40^m.0159.

B. M. 95 is the center of head of copper bolt leaded horizontally into the west side of the brick chimney at the north end of the dwelling-house on Wade Lawn Plantation, owned by Mr. V. Preston, about one-fourth mile below Mayersville, Miss. The bolt is about 2 meters above the ground. Elevation, 40^m.3005.

B. M. 105 is the center of head of a copper bolt leaded horizontally into the brick chimney of gin-house on Reserve Plantation, owned by Mr. S. Duncan. The bolt is in the center of a brick on the west side of the chimney and about 1¼ meters from the ground. The gin-house is about one-fourth mile from the levee, and about 3¼ miles above Ben Lomond P. O., Issaquena County, Mississippi. Elevation, 39^m.2393.

B. M. 112 is the center of head of copper bolt leaded horizontally into the brick chimney of gin-house on Ben Lomond Plantation, owned by George M. Brown. The gin-house is about 600 meters from the levee, and just back from Ben Lomond P. O. The bolt is in the center of a brick on the west side of the chimney and about one meter and a half from the ground. Elevation, 39^m.4508.

B. M. 124 is the center of head of copper bolt leaded horizontally into the brick foundation of Tallulah post-office building, better known as "Old Tallulah Court-House," about 2 miles above Tallulah Landing, Issaquena County, Mississippi. The bolt is near the southeast corner of the house, and about 1 foot above the ground. Elevation, 37^m.9932.

B. M. 128 is the center of head of copper bolt leaded horizontally into the brick foundation of the dwelling-house on Lockwood Plantation, owned by R. B. Phipps. The house is about one-third mile above Tallulah Landing. The bolt is near the southeast corner of the house, in the twentieth brick from the bottom and third from the southeast corner. Elevation, 38^m.5891.

B. M. 137 is the center of head of copper bolt leaded horizontally into a brick pillar supporting the porch of dwelling-house on Elliston Plantation, owned by Mr. F. W. Hays, a little below Hays P. O., Issequena County, Mississippi. The bolt is near the middle and top of the first pillar to the right of the steps leading up to the porch. Elevation, 38^m.4772.

B. M. 140 is the center of head of a copper bolt leaded horizontally into brick chimney of cotton-gin on Shiloh Plantation, owned by Mr. J. W. Heath. The bolt is in the fourth brick from a row of projecting bricks, near the center of the north side of chimney, and about 7 feet from the ground. The letters U. S. B. M. are cut in the surrounding bricks. Elevation, 40^m.0023.

B. M. 150 is the center of head of a copper bolt leaded horizontally into brick chimney of dwelling-house owned by Mr. Z. Leatherman, about 4 miles below Hays's P. O., and about the same distance above Ingomar P. O., Issaquena County, Mississippi. The bolt is in the second brick from the southwest edge of chimney, and about 4.5 feet above the ground. Elevation, 38^m.3523.

B. M. 153 is the center of head of a copper bolt leaded horizontally into brick chimney of cotton-gin, owned by Dr. J. W. Butts, on Tennessee Plantation, about 3.5 miles above Ingomar P. O., Issaquena County, Mississippi. The bolt is on the west side of chimney and near the southwest corner. The letters U. S. B. M. are cut in the surrounding bricks. Elevation, 38^m.0187.

B. M. 161 is center of head of copper bolt leaded horizontally into brick chimney of a cabin on the Henderson Plantation, owned by Mrs. Emma E. Peck, in East Carroll Parish, Louisiana. The cabin is about three-fourths mile from Henderson's Landing. The bolt is in the east face of the chimney and the letters U. S. B. M. are cut in the surrounding bricks. Elevation, 36^m.4223.

B. M. 162 is center of head of copper bolt leaded horizontally into west face of brick pillar of dwelling-house owned by Mrs. Emma E. Peck, on the Henderson Plantation, about one-eighth mile above Henderson Landing, East Carroll Parish, Louisiana. Elevation, 37^m.2306.

B. M. 171 is center of head of copper bolt leaded horizontally into brick chimney of dwelling-house owned by Mrs. Sarah E. Nutt, on Ditchley Plantation. The house is about one-fourth mile above Omega P. O., Madison Parish, Louisiana. Elevation, $35^m.6283$.

B. M. 179 is center of head of copper bolt leaded horizontally into brick foundation of dwelling-house owned by Mr. H. P. Morancy, on English Field Plantation, Madison Parish, Louisiana. The bolt is in the sixth brick from the top of the foundation and in the third from the northwest corner. The house is about three-fourths mile above Milliken's Bend and about a half mile from the river. Elevation, $35^m.9253$.

B. M. 184 is center of head of copper bolt leaded horizontally into brick pillar supporting northeast corner of porch of dwelling-house owned by the Citizens' Bank of Louisiana, on River View Plantation, Madison Parish, Louisiana. The house is about one and one-fourth miles below Milliken's Bend, and about one-fourth mile from river. Elevation, $34^m.9761$.

B M. 188 is center of head of copper bolt leaded horizontally into east face of brick pillar supporting northeast corner of dwelling on Cabin Teele Plantation, owned by Mrs. L. R. Marshall. The house is about three and one-fourth miles below Milliken's Bend, and a half mile from the river. Elevation, $36^m.2719$.

B M. 197 is center of head of copper bolt leaded horizontally in center of face of middle brick of third course from top, of third pillar from northeast corner of porch of dwelling-house on Duck Port Plantation, Madison Parish, Louisiana, owned by Mr. G. L. Barrey. Elevation, $35^m.8365$.

B. M. 207 is center of head of copper bolt leaded horizontally in the south chimney of dwelling-house on Echo Plantation, Madison Parish, Louisiana, owned by Mattingly and Flowerce. The bolt is in the third brick from the southeast corner and in the twenty-first course from the ground. Elevation, $35^m.9813$.

B. M. 211 is center of head of copper bolt leaded horizontally in center of face of middle brick of eighth course from the ground of second pillar from southeast corner of porch of dwelling-house owned by Goodman and Bradford, on Willow Glen Plantation, Madison Parish, Louisiana. Elevation, $33^m.9698$.

B. M. 215 is the end of the vertical ray of a five-rayed cast-iron star on the south end of parish clerk's office, a brick building near the court-house in Delta, Madison Parish, Louisiana. The star is a tie-rod plate, and is about 4 feet from the ground, and three feet from the southeast corner of the building. Elevation, $34^m.0836$.

B. M. 225 is center of head of copper bolt leaded horizontally in center of face of middle brick of tenth course from the ground, of second pillar from southeast corner of dwelling-house owned by Mr. G. W. Bedford, on Point Place Plantation, Madison Parish, Louisiana. The house is about three-fourths mile from the river and opposite Warrenton, Miss. Elevation, $33^m.9202$.

B. M. 232 is the center of head of copper bolt leaded horizontally in east chimney of dwelling-house owned by Mr. Orange Christmas, on Crystal Springs Plantation, Madison Parish, Louisiana. The brick is the second from the southeast edge of chimney and is in the twelfth course from the ground. The house is about 4 miles below Warrenton, Miss., and about 2 miles from the Mississippi River. Elevation, $32^m.9195$.

B. M. 243 is center of head of copper bolt leaded horizontally in the middle of south face of southeast chimney, 15 inches from the ground, of Kellogg's P. O. building, Madison Parish, Louisiana. The building is owned by W. D. White of Kentucky and is about 400 meters from the river. Elevation, $33^m.1167$.

B. M. 246 is top of a copper bolt in top of cement post 3 feet long and 8 inches in diameter, set in the ground on Sargent's Point Plantation, Madison Parish, Louisiana, owned by Mrs Rachel Wilkinson. The cement post was set with top flush with surface of ground, and is about 600 meters from the river. It is near some cabins around which are water-oak and pecan trees. Two of the water-oaks, 11.2 and 10.5 meters distant from the bench-mark, were marked with triangular blazes. Elevation, $32^m.3326$.

B. M. 258 is center of head of copper bolt leaded horizontally in a brick about 4 feet from the ground and about the middle of the north face of the north chimney of dwelling owned by Mr. George W. Turner, on Point Pleasant Plantation, Tensas Parish, Louisiana. The house is about one-third mile from the river. Elevation, $32^m.9677$.

B. M. 262 is center of head of copper bolt leaded horizontally in center of face of middle brick of the twelfth course from the foundation in the south face of the east chimney of dwelling owned by Mr. E. Loyd, on Riverside Plantation, Tensas Parish, Louisiana. The house is about one-half mile from the river. Elevation, $31^m.6104$.

B. M. 272 is top of copper bolt in top of cement block 18 inches long and 8 inches in diameter set in ground on Hard Times Landing, Tensas Parish, Louisiana, owned by Mrs. G. H. Hollingsworth. It is about 600 meters from the Mississippi River, about 50 meters from the bank of Lake St. Joseph, and near a cabin. Elevation, $30^m.3201$.

B. M. 280 is center of head of copper bolt leaded horizontally in center of face of middle brick of tenth course from the foundation, in the southeast face of brick chim-

ney of gin-house on Waveland Plantation, Tensas Parish, Louisiana, owned by Mr. John Bondurant. The gin-house is about 500 meters from the bank of the river and about 8 kilometers above St. Joseph, La. Elevation, $30^{m}.0533$.

B. M. 286 is center of head of copper bolt leaded horizontally in center of face of fourth brick from northeast corner, twenty-third course from ground, of brick chimney of gin-house on Panola Plantation, owned by J. M. Gillespie. It is about 2 kilometers above St. Joseph, La., and about 1 kilometer from the river. Elevation, $31^{m}.1115$.

B. M. 291 is center of head of copper bolt leaded horizontally in north face of brick chimney of gin-house on Duck Pond Plantation, owned by Captain Robert Worrell. The bolt is in fifth brick from the northeast edge of chimney and in the seventh course below the projecting course. The gin-house is about 2 kilometers below St. Joseph and about 500 meters back from St. Joseph Landing. Elevation, $29^{m}.3873$.

B. M. 297, or LXXIII, is a marble post buried in the ground on the left of, and quite near, the steps leading to the front entrance of Captain E. L. Whitney's residence on Villa Clara Plantation, Tensas Parish, Louisiana; Bieller's Landing is on Villa Clara Plantation. The post is 5 inches square and 2 feet 6 inches long, and the top is marked thus:

U. S.
B. ▭ M. The bottom of the cavity was used as the bench-mark. Elevation, $27^{m}.8439$, 1881.

B. M. LXXII is bottom of cavity in top of marble post, 5 inches square and 2.5 feet long, buried in the ground on the right and near the front entrance of Mr. W. H. Goldman's residence on Stockridge Plantation, at Kemp's Landing, Tensas Parish, Louisiana. Elevation, $28^{m}.3007$.

B. M. LXXI is bottom of cavity in top of marble post, 5 inches square and 2.5 feet long, buried in the yard on the left of, and quite near, the steps leading to the front entrance of Mr. A P. Martin's residence at Water Proof, Tensas Parish, Louisiana. Elevation, $26^{m}.6946$.

B. M. LXX is a cross cut on the top surface of an old cistern which is in an open field about 3 miles below the town of Water Proof, La. The cistern is about 50 meters from the main levee and 190 meters from junction of main and old levees, marked with the letters U. S. B. M., 1881. Elevation, $26^{m}.8774$.

B. M. LXIX is the head of copper tack in cedar stub which marks the center of triangulation station Duncan, just above L'Argent, Tensas Parish, Louisiana. Elevation, $28^{m}.0397$.

B. M. LXVIII is a cross cut on top of cistern in yard of house on Agnasea Plantation, about one-half mile below L'Argent Landing. The bench-mark is on west side of top of cistern, marked with the letters U. S. B. M. Elevation, $27^{m}.3280$.

B. M. LXVII is bottom of cavity in top of marble post buried in the ground within the inclosure on the right of Stanton & Brandon's Store, and near the corner of the store at Gibson's Landing, Concordia Parish, Louisiana. The top of the post is about 4 inches above ground. Elevation, $26^{m}.3175$.

B. M. LXVI is bottom of cavity in top of marble post buried in the ground on the right of, and quite near, the steps leading to the front entrance of Mr. E. W. Walls' residence at Bullit's Bayou (Good Hope) Landing. The top of the post projects 4 inches above the ground. Elevation, $25^{m}.8329$.

B. M. LXV is bottom of cavity in top of marble post buried in levee opposite an old brick wall about 4.5 miles above Vidalia, La. The post is 11 meters south of a lone tree and 10 meters south of the brick wall, and its top projects 4 inches above ground. Elevation, $27^{m}.0146$

B. M. LXIV is cross cut in top of iron screw pile marking triangulation station Palo Alto, about one mile north of Vidalia, La. It is on the west side of the road and about 250 meters from it. Elevation, $25^{m}.9332$.

B. M. LXIII is top of copper bolt in center of top of monument marking southeast end of the Vidalia base line. The monument is in a lot immediately back of the court-house and jail at Vidalia, is 14 inches square at top, and projects 14 inches above ground. Elevation, $24^{m}.8472$.

B. M. LXII is bottom of cavity in top of marble post buried in the ground near steps leading to the front entrance of Judge W. H. Hough's residence in Vidalia, La. The post is on the right of the steps and its top is about 4 inches above ground. Elevation, $25^{m}.4965$.

B. M LXI is cross cut in top of iron screw pile marking triangulation station Gaither. It is about one mile below Vidalia, in an open field and on right-hand side of road leading to Vidalia. Elevation, $24^{m}.9452$.

B. M. LX is bottom of cavity in top of marble post buried in the ground on the right of, and quite near, the steps leading to the front entrance of Mr. Abner Crother's residence on Moro Plantation, about 9.75 miles below Vidalia. The top of post is about 5 inches above ground. Elevation, $25^{m}.7543$.

B. M. LVIII is center of top of granite post marking triangulation station Ashley, on Ashley Plantation, Concordia Parish, Louisana. It is about 2 miles below Morville

Landing is 300 meters south of Willow Grove, 160 meters east of levee, and 15 meters from river. Elevation, 22$^{\mathrm{m}}$.6927.

B. M. LVII is bottom of cavity in top of marble post buried in ground just east of steps leading to front entrance of residence on Deer Park Plantation, owned by Mr. A. D. Rawlings. The top of the post is about 3 inches above ground. The house is about one-fourth mile from the river, south of the main road leading to Vidalia, and about 24 miles below Vidalia. Elevation, 24$^{\mathrm{m}}$.2349.

B. M. LVI is center of top of limestone post marking triangulation station Pecan, on Pecan Plantation, owned by Mr. Sargent Shields, Concordia Parish, Louisiana. The station stands 30 meters from the bank on the top of the State levee running across Esperance Point. A small levee starts out to the west 4 meters to the north of the station. It is 50 meters south of where road crosses main levee. Elevation, 25$^{\mathrm{m}}$.0699.

B. M. LV is top of marble post buried in the ground to the right of the steps leading to the front entrance of the residence on Braleston Plantation, near Fairview P. O., Louisiana. The top of stone is about 3 inches above ground. Elevation, 23$^{\mathrm{m}}$.3177.

B. M. LIV is top of granite post buried in the ground on the left of the steps leading to the front entrance of Mr. William G. Walton's residence on Ashland Plantation near Bougere P. O., Louisiana. The top of stone is about 3 inches above ground. Elevation, 23$^{\mathrm{m}}$.5622.

B. M. LIII is top of granite post buried in the ground to the right of the steps leading to the east entrance of Mr. Ed. Pullen's residence, at Black Hawk P. O., Louisiana. The top of post is about 3 inches above ground. Elevation, 22$^{\mathrm{m}}$.1282.

B. M. LII is cut in the brick top of cistern used to supply with water the engine of gin-house on Ballamagan Plantation, Concordia Parish, Louisiana. The cistern is quite near, and on the right of road leading from Point Breeze to Black Hawk, and is about 3 miles from the latter place. The B. M. is marked thus: B. $\underset{\text{LII.}}{\overset{\text{U. S.}}{\square}}$ M. Elevation, 23$^{\mathrm{m}}$.3903.

B. M. LI is top of copper bolt in top of stone monument marking the northeast end of Lum's Point base line on Point Breeze Plantation, Louisiana, owned by Mr. Trager. Elevation, 22$^{\mathrm{m}}$.3926.

B. M. L is top of copper bolt in top of stone monument marking the southwest end of Lum's Point base line, in Concordia Parish, Louisiana, nearly opposite Fort Adams, Miss. The bench-mark is on the place owned by Mr. Lum, of Vicksburg, and occupied by Mr. A. A. Cox. It is on the west side of a farm road in a cultivated field and very near a gate. Elevation, 22$^{\mathrm{m}}$.3519.

B. M. XLIX is a granite post buried at the southwest corner of the house of Mr. J. R. Mathews, just above the corners at the upper end of the village of Fort Adams, Wilkinson County, Mississippi. Elevation, 27$^{\mathrm{m}}$.0271.

B. M. XLVIII is a granite post buried at the southeast corner of the store of Lehmann and Lauenburgh, back of an old cotton-gin a short distance above Clarksville Landing, Wilkinson County, Mississippi. The store is at the point where the road from Fort Adams, after crossing the hills, comes out on the low plateau extending to the river. Elevation, 30$^{\mathrm{m}}$.1924.

B. M. XLVII is a granite post placed close to the back fence of the yard around dwelling on Tarbert Plantation, Wilkinson County, Mississippi. The plantation lies between Angola and Langside Plantations, extends beyond the State line, and is owned by Mr. Jenkins, of Natchez. Elevation, 21$^{\mathrm{m}}$.3066.

B. M. XLVI is cut on top of the circular wall forming the mouth of a cistern, just back of house on Angola Plantation, West Feliciana Parish, Louisiana. It is nearly opposite mouth of Red River. The brick work is covered with cement, through which a square aperture was cut, exposing the upper surface of the brick. This brick surface was used as the bench mark. Elevation, 22$^{\mathrm{m}}$.5666.

B. M. XLV is a granite post placed in the yard of Mr. Archie Smith, near Hog Point Landing, Smithland P. O., Point Coupee Parish, Louisiana. Elevation, 20$^{\mathrm{m}}$.9832.

B. M. XLIV is a granite post placed just beside the front steps of Dr. A. A. Batchelor's house, on Belle Vista Plantation, on Old River, Point Coupée Parish, Louisiana. Elevation, 19$^{\mathrm{m}}$.9110.

B. M. XLIII is a granite post in front of house of Mr. Edgard Lacour, close to Raccourci Landing, Point Coupee Parish, Louisiana. Elevation, 17$^{\mathrm{m}}$.9799.

B. M. XLII is top of granite post buried with top 3 inches below surface of ground, at the junction of the "Grand Levee" and a branch levee running to Morganza Landing. It is about half a mile below Morganza. Elevation, 20$^{\mathrm{m}}$.4780.

B. M. XLI is a granite post placed beside the front steps of house on Morrison Plantation, Point Coupee Parish, Louisiana. Elevation, 18$^{\mathrm{m}}$.4308.

B. M. XL is a granite post placed by the side of the front steps of house on Poydras Plantation, Point Coupee Parish, Louisiana. It is about half a mile above the "New Road" leading to the Court House at False River. This part of the parish is known as the "Point Coupee Settlement." Elevation, 17$^{\mathrm{m}}$.5072.

B. M. XXXIX is top of copper bolt in limestone monument at the northwest end of base line directly opposite Bayou Sara, Louisiana. Elevation, 18m.0263.

B. M. XXXVIII is top of copper bolt in limestone monument marking southeast end of base line nearly opposite Bayou Sara, Louisiana. Elevation, 18m.1595.

B. M. XXXVII is upper edge of a mark cut on the front of the "Saint Claude Store" at Waterloo, Point Coupee Parish, Louisiana. The store is built of brick and belongs to Mr. Robin. The bench-mark is nearly on the middle line of the front and is 5.44 feet above the ground. Elevation, 19m.8775.

B. M. XXXVI is a granite post placed in front of the house of Mr. C. Devall, Sans Souci Plantation, West Baton Rouge Parish, Louisiana. The house fronts on a bayou, the remains of the old river channel, and is on the road leading directly back from Hermitage Landing. Elevation, 17m.6413.

B. M. XXXV is a granite post placed in the back corner of the inclosure around the "Kelson Store," owned by Capt. John J. Brown, West Baton Rouge Parish, Louisiana. The store is opposite the upper part of Profit Island. Elevation, 16m.6859.

B. M. XXXIV is a granite post in front of the house of Mr. B. Chamberlain, jr., and is about a half a mile above Lobdell's Store, at Grossman's Landing, West Baton Rouge Parish, Louisiana. Elevation, 15m.7861.

B. M. XXXIII is a granite post buried in front of the pillar at the northwest corner of house of Mr. A. Guesnard, Belmont Plantation, West Baton Rouge Parish, Louisiana. Elevation, 15m.5322.

B. M. XXXII is a granite post buried in the flower garden in front of house on plantation of Mr. J. H. Gay, West Baton Rouge Parish, Louisiana. The plantation is directly opposite the city of Baton Rouge, and just below the ferry landing. Elevation, 14m.8454.

B. M. XXXI is a bench-mark of the U. S. Engineers. It is the edge of one of the foundation courses of the tower on the north side of the western entrance to the State-house at Baton Rouge, Louisiana. It is marked, U. S. E. Elevation, 25m.1920.

B. M. XXX is the surface of the limestone monument at the north end of Baton Rouge base line. It is situated in a cane-field belonging to Messrs. Weeks and McCullan, 700 meters south of Baton Rouge city limits, and 97 meters from river road. Elevation.

B. M. XXIX is a point surrounded by a shallow groove upon the top of the limestone monument at the south end of Baton Rouge base line. It is 1,622 meters from North Base, is between the river road and the levee, is 42 feet from angle of levee and 29.7 feet from corner of fence. Elevation, 14m.7455.

B. M. XXVIII is a granite post placed in the front yard, close to an old brick pier, of house on Arlington Plantation, East Baton Rouge Parish, Louisiana. The plantation is 4 miles below Baton Rouge, and belongs to Mr. Shannon. Elevation, 15m.5313.

B. M. XXVII is a granite post buried close to the front gate of inner yard about Mr. Conrad's house on Cottage Plantation, about 8 miles below Baton Rouge, Louisiana. Elevation, 15m.6911.

B. M. XXVI is a granite post, 8 meters from fence at side of road and on the line of a row of old fig trees, 23 meters east of house on Hollywood Plantation, East Baton Rouge Parish, Louisiana. The house is 12 miles below Baton Rouge, half a mile above Manchac P. O., and belongs to Mr. H. Vonpuhl. Elevation, 15m.3510.

B. M. XXV is a granite post in the northeast corner of the yard of Mr. Walter Humble, on Anger's Plantation, Iberville Parish, Louisiana. The house is about 5 miles above Plaquemine, is a short distance west of the road which runs across the point to Forlorn Hope P. O. Elevation, 14m7924.

B. M. XXIV is a granite post near the corner of the yard, about house of Mr. Daigre, the overseer of Anger's Plantation, Iberville Parish, Louisiana. The house is the second one below Forlorn Hope P. O., and just above a bend in the road. Elevation, 14m.2470.

B. M. XXIII is a granite post in the front yard of Julian Grassin, next to Saint Gabriel's church, Saint Gabriel, La. The plantation formerly belonged to Dr. Pritchard, and is 4 or 5 miles above Bayou Goula. Elevation, 13m.3389.

B. M. XXII is a granite post buried in yard on plantation of Leach, Seaward and Thompson, about a mile above Bayou Goula, and on opposite side of river. The house is a low frame building, and there is a pumping-engine on the levee about 200 yards above the house. Elevation, 14m.2773.

B. M. XXI is a granite post buried near angle formed by a wing and central portion of house owned by Mrs. Buddington, on Indian Camp Plantation, Iberville Parish, Louisiana. Elevation, 14m.4248.

B. M. XX is a point on the upper surface of the projecting brick foundation running around the house, on Southwood Plantation, formerly called Hard Times, at the extreme upper end of Ascension Parish, Louisiana. A square opening was cut through the stucco covering so as to allow the rods to rest upon the brick. The bench-mark is marked with the letters U. S. B. M. and the date 1880. Elevation 13m.5083.

B. M. XIX is a cross-cut on the head of an iron bolt in the north end of the brick

warehouse at Ashland Landing, Ascension Parish, Louisiana. The bolt is 4.8 feet above the ground, and is in the middle of the wall. The bench-mark is marked by the letters U. S. B. M. XIX, 1880, cut in the wall. Elevation, 15^m.7964.

B. M. XVIII is a granite post buried in the front yard of Mr. V. P. Mirre, Ascension Parish, Louisiana. The place is about 4 miles above Donaldsonville, and formerly belonged to E. Dicharvy. Elevation, 12^m.3899.

B. M. XVII is a granite post buried in yard at side of house of Mr. Heath on left bank of river about a mile above Donaldsonville, La. Elevation, 12^m.9014.

B. M. XVI is point surrounded by a groove forming a small square on limestone slab at side of front steps of Mr. Hagan's house, about 6 miles below Donaldsonville. It is marked with the letters U. S. B. M. Elevation, 13^m.8985.

B. M. XV is on the corner of the stone pedestal of a pillar by the side of the entrance to the house of Mr. Colomb, Saint James Parish, Louisiana. The point on which the rods were held is surrounded by a groove cut in the stone, and is marked by the letters U. S. B. M. XV. Elevation, 13^m.4721.

B. M. XIV is the bottom of a shallow square cavity cut in the granite step of the south door on the front or west side of the Convent of the Sacred Heart, Saint James Parish, Louisiana. The bench-mark is marked with the letters U. S. B. M. Elevation, 13^m.6700.

B. M. XIII is a horizontal line cut in the iron post on the south side of the gateway in front of Jefferson College, on College Point just below the settlement known as Saint Michaeltown, Saint James Parish, Louisiana. The post was marked with the letters XIII, U. S. B. M. LXXX. Elevation, 14^m.2580.

B. M. XII is bottom of a square cavity cut in the cement pedestal of the column at the southwest corner of house of Mr. Louis Lebourgeois on Belmont Plantation, Saint James Parish, Louisiana. It is marked with the letters U. S. B. M. Elevation, 12^m.1979.

B. M. XI is upper edge of triangular groove cut in west side of small pier supporting the southwest corner of a wooden warehouse which stands upon the levee nearly in front of house of Mr. Wallis on Belle Alliance Plantation, Saint James Parish, Louisiana. The center of the line is 4.2 feet above a projecting foot-course, and 1.3 feet from the outer corner of the pier. It is marked by the letters U. S. B. M. 1880 IX. Elevation 13^m.3741.

B. M. X is a point surrounded by a groove cut in the upper surface of the granite sill at the foot of the iron stairway in front of house of Mr. Joseph Lebourgeois, on Mount Airy Plantation, Saint John Baptist Parish, Louisiana. It is marked by the letters U. S. B. M. 1880. Elevation, 11^m.8547.

B. M. IX is upper edge of horizontal groove cut in the west wall at the southwest corner of store on Terre Haute Plantation, Saint John Baptist Parish, Louisiana. The groove is 5.15 feet above the ground, and 0.32 feet from the edge of the brick wall. It is marked by the letters IX U. S. B. M. 1880. The plantation is just above the settlement at Bonnet Carré, and belongs to Mr. James W. Godberry. Elevation, 13^m.0218.

B. M. VIII is the head of a long iron bolt in a cement post in the yard of Mr. Adam Lasseigne, just above the post-office at Bonnet Carré, La. Elevation, 11^m.2570.

B. M. VII is the head of an iron bolt in a cement post at the foot of a large pecan-tree in front of house on estate of Mr. Ambruster, Saint Charles Parish, Louisiana. It is about a half mile below the Gypsy Plantation, owned by Mr. Labranche, which, is at the bend of the river below Bonnet Carré Crevasse. The hole above the bench-mark was filled with broken bricks, and covered over with earth. It is 1.7 and 1.9 feet, respectively, from two nails driven in projecting roots of the tree. Elevation, 11^m.1901.

B. M. VI is the upper surface of the square pedestal of the pillar on the eastern side of the front steps of Mr. Leon Sarpy's house, on Prospect Plantation, Saint Charles Parish, Louisiana, and nearly opposite Hahnville. The pedestal is of brick, covered with hard stucco. The point on which the rods where held is surrounded by a groove forming a square, and the letters U. S. B. M. 1880, are cut on the surface. Elevation, 10^m.5504.

B. M. V is the surface of the stone sill of the footway on the western side of the main entrance to Destréhan Plantation, owned by Judge Rost, Saint Charles Parish, Louisiana. The point on the stone on which the rods were held is surrounded by a groove cut in the stone, and marked by the letters U. S. B. M. Elevation, 11^m.1258.

B. M. IV is the head of an iron bolt imbedded in a cement post on the levee about 4 miles above Kennerville, and nearly in front of the house of Norbert Longue. It is 9.4 feet from the second and 11 feet from the third tree from the road on the east side of the avenue leading to the river. Elevation, 11^m.6957.

B. M. III is the bottom of a square depression in the top of a granite block buried in the yard of Dr. Gustine at Kennerville, Jefferson Parish, Louisiana. The stone is 26 meters in front of the house, and 3.5 meters from a date palm, and is marked with the letters U. S. B. M. Elevation, 9^m.6899.

B. M. II is the bottom of a slight depression in the upper surface of a cement post on the inner levee in front of Mr. Soniat's house at Twelve Mile Point, 5 miles above Carrollton, La. It is 24 paces above the corner of the road, and 25 paces below the gateway. The top of the post is marked with the letters U. S. B. M. 1880. Elevation, $11^{m}.9489$.

B. M. I is the intersection of two cross lines cut on the iron sill of a door at the northwest corner of the depot at Carrollton, La. It is marked with the letters U. S. C. S. B. M. 1875. Elevation, $9^{m}.0272$.

APPENDIX C.

REPORTS OF CHIEFS OF PARTIES UPON FIELD WORK OF TOPOGRAPHY AND HYDROGRAPHY, 1883–'84.

1.—*Report of Assistant Engineer J. A. Ockerson, Randolph Point to Frame's Chute, and Campbell's Landing to Saint Louis Landing.*

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., September 1, 1884.

SIR: I have the honor to make the following report on the field work done under my direction during the season of 1883–'84. Accompanying this report are also the results of investigations concerning sliding banks, changes in the bank-line and section of the Mississippi River between Cairo and Saint Louis Landing, and data concerning the relative elevations of old river banks and those of later formation.

In accordance with your instructions to proceed to Randolph Point to continue the survey of the Mississippi River, the party left Saint Louis on October 10, 1883, for Cairo, where the quarter-boats were in readiness to receive them. The organization was as follows: J. A. Ockerson, chief of party; topographers, C. W. Clark, N. B. Craig, J. C. Quintus, H. P. Ritter, F. Felkel, and F. B. French; hydrographers, B. H. Colby and J. N. Allison; levelers, I. O. Walker and C. Brainard; plotting and computing, E. J. Jolley; a launch crew of 3; galley crew, 6; leadsmen, 2; rodmen, 8; boatmen and axmen, 20.

The supplies had already been delivered on board, and on the arrival of the parties the boats were taken in tow by the steamer Patrol and reached Randolph Point on the 15th of October. The topographers began work immediately.

The instructions required that the work of 1879–'80 should be utilized as far as practicable. But little use could be made of it as the survey was done at a high-water stage. The triangulation and levels were, of course, available.

The reach from Randolph Point to head of Frame's Chute was completed on October 30, and after taking on coal at Memphis the party moved down to Campbell's Landing to resume the survey where the work under General Comstock closed in 1878. Work began at this point on November 1, and was completed to Saint Louis Landing on December 28.

The survey embraces, outside of the usual mile limit, the Saint Francis River from a point opposite Dupries Landing to the mouth, a distance of about 18 miles, McKinney Bayou, and the following lakes: Beaver Dam, Flower, Porter, Eagle, Moon, Mud, and Horseshoe. The bluff line was also located from near the mouth of the L'Anguille to about 4 miles below Helena, and from the Loosahatchie River to a point opposite the head of Island 40.

The season throughout was unusually good both as to stage of river and weather. Out of the sixty three working days the party was in the field, there were only three rainy days, on which no field work was done.

On the completion of the survey to Saint Louis Landing, where it closed on the work of 1881, the party was disbanded.

The steamer Patrol arrived on the day the work was finished, and on the day following the quarter-boats were taken in tow for Memphis.

The accuracy and progress of the work must be largely credited to the fidelity and industry of the assistants.

The following tabulated statement shows in detail the amount of work done:

Number of miles of river surveyed	92
Number of square miles of topography	227
Number of square miles of hydrography	64
Number of soundings	15,064
Number of sextant angles read	14,708
Number of working days	63
Average number of miles of river per month	37
Average number of square miles of topography and hydrography per month	117

DEPOSITS MADE BY THE RECENT FLOODS.

In some places the deposits have been quite heavy. On both sides of the river above Frame's Chute, even on the high bank, there has been a deposit of several inches since the survey of 1877-'78. On the lower lands the deposit amounts to 5 feet in some cases. These deposits sometimes consist of pure sand, which ruins cultivated lands and even kills the trees. One curious effect of the deposit was noticed on triangulation lines which were cut through young cottonwoods and willows 3 inches in diameter and upwards. The stumps, which were from 1 to 3 feet high, have been covered with the deposit, and the fallen trees either washed away or covered up, so that now the line is left intact and smooth.

There is not so much as a weed in it, and all evidences of the cutting except the opening have disappeared.

There are numerous places where no deposits have been made, although the conditions are apparently the same as where there are heavy deposits. The first surveys are so meager in detail that a satisfactory comparison concerning deposits in general cannot be made.

Deposits of gravel have been noticed on the highest lands. This may have come from the logs and trees floated from the bars by the rising river. The heavy sand deposits noted must have been carried in suspension and dropped where the velocity was diminished by the water leaving the channel.

STABILITY OF STONE LINE BENCH-MARKS.

Nearly all of the bench-marks were found intact after having stood the tests of the floods for three years. Some of them were covered to a depth of several inches by deposits of silt and sand. As a rule the inhabitants do not molest them. Occasionally a fisherman in need of sinkers digs them up, and after breaking them into suitable sizes ties the pieces to his net. One was found with the lead and copper bolt dug out. The surface marks were not frequent nor conspicuous enough.

It is very important to have numerous surface marks or the bench-marks will be lost in consequence of changes in bank line, clearing off or growing up of timber, and deposits of silt.

I would here call attention to the advisability of limiting the number of bench-marks in the same locality. It has been the custom of each party sent out for high-water slope, low-water slope, &c., to establish independent bench-marks. Hence it frequently happens that within a radius of a few hundred meters may be found P. B. Ms., B. Ms., B. M. L., B. M. E., &c. After the value of one has been well determined it should be used. A multiplicity of bench-marks in the same vicinity must ultimately result in confusion, while there is no good reason apparent why every new party sent to the field should have a separate and exclusive series of benches.

NARROW CHANNEL.

Just below Moon Lake Landing the river becomes very narrow in consequence of the sand-bar pushing far over into the bend. The width between shore lines at a stage about 6 feet above low water is only 290 meters. The maximum depth in the narrowest part is about 65 feet.

SLIDING BANKS.

In Old Town and Montezuma bends are two peculiar cases of sliding bank, where the land settles down bodily, leaving the trees upright, where they act as a natural revetment and remain a long time before being washed away. Plats of these two localities are submitted herewith, which show these bends and sections of same. The slide in Old Town Bend extends, from a point three-fourths of a mile above the landing, down-stream for a distance of about 2¼ miles. Near the lower end the slide reaches a width of 300 feet. The disintegration seems to be very slow after the ground settles. The survey of February, 1881, shows the outer line of trees in the same position as given by the survey of December, 1883, for more than half the length of the slide. Near the lower end the caving amounts to about 30 meters per year. The deepest part of the channel runs very close to the submerged trees.

The soil of the adjacent bank is a tough alluvial clay covered with a growth of heavy timber. The presence of cypress, and the low land, indicate that it was formerly a swamp or lake, or it may have been the bed of the river at some remote period. The water in the bayou and lake back is some 10 feet higher than low water in the river.

In Montezuma Bend there is a slide about half a mile long and 100 feet wide in the

broadest part. The shore-line in the apex of the bend has receded about 20 meters a year since the survey of 1878. The banks consist of layers of clay and sand. They are formed by deposits in the old river-bed after the cut-off at Mhoon Lake. The old river bank was undoubtedly near where the levee is now located. It will be observed that a pond lies parallel to the shore-line for the entire length of the slide. The water in the pond lies several feet higher than the ordinary water surface in the river.

It is probable that these slides are due to the washing out of the sand layers by the river, aided very largely by the water in the ponds near by. The latter lying so far above the river play an important part in the destruction of the banks.

This is probably the reason why the banks cave more rapidly when the river is below the medium stage and falling rapidly. This is especially the case with banks composed wholly or partly of clay; sandy banks cave at all stages.

In order to ascertain how far the influence of surface water extends, 66 cases of caving banks between Memphis and Natchez have been examined in detail, with the following results: In 25 cases where there is rapid caving, there is more or less standing water near the river. The banks in these cases are generally more sandy and friable than the two cases above noted, which probably accounts for their caving in smaller fragments.

The other cases are generally traceable to obstructions in the channel which forces the current against the bank, or to the loose sandy nature of some of the banks.

STABLE BANKS.

There are bends where the banks are quite stable, and in some of these cases the shape of the channel is such that caving would naturally be expected. Between Island No. 1 and Island No. 10 we find "Iron Banks" and "Chalk Bluffs" where the river is held by the bluffs. In the bend below Hickman the caving is slight. The bank is composed of layers of clay separated by sand. For 3 miles the main current is kept out from the bank, probably by underlying rocks or clay lumps. Below James Bayou the bank is very largely clay and caves slowly.

In the next available reach, which is between Caruthersville and Frame's Chute, the bend above Booth's Point is found to be quite stable. The bank is said to be mostly blue clay.

Opposite Island No. 18 the bank is clay and sand, but a bar keeps the current away from the bank and it caves but little. Chickasaw Bluff No. 2, near the whirlpool, caves slowly. In the bend opposite Island No. 40 there has been but little caving. A bar has formed which is attached to the concave bank.

Above the mouth of the Saint Francis River the bank is mostly clay. For 2½ miles the current follows the bank closely and yet the caving is slight. One point in particular which juts out some 50 feet from the bank and is not more than 10 feet wide on top has stood the wear of the current for several years. It was noticed in the survey of 1878 and has changed but little since then.

The pertinacity with which deep indentations in the banks remain for years in the same locality is as remarkable as the stability of the clay points. Cases have been noticed where they have existed for several years, although the entire bank-line has receded over 1,000 feet.

ELEVATIONS OF PRESENT RIVER BANKS AS COMPARED WITH BANKS OF CUT-OFF LAKES.

It is frequently stated that the banks of the old river lakes are higher than the present river banks. It is generally conceded that the banks of alluvial streams reach an elevation equal to the plane of mean high water.

If the first proposition is true, then the floods which deposited these old river banks, dating back many years prior to the settlement of the Mississippi Valley, must have been higher than those of recent years of which we have authentic records.

This does not accord with the theory that cutting down the forests, bringing the land under cultivation and confining the river between levees, all tend to increase the flood heights.

It is to throw some light on these questions that an examination has been made of all cases where the elevations of the old river banks were determined by the recent surveys.

The elevations are generally reliable to the nearest foot. They were determined by vertical angles, read forward and back with a transit. If the elevations were more numerous, the comparisons would of course be more satisfactory.

The distance given in the following descriptions are measured from the present river bank to the farthest point in the old river lake. Maps of eight old lakes and adjacent river have been reduced and are submitted herewith.

They show the elevations in feet above the Memphis datum plane.

Beaver Dam Lake, near Austin.—Date of cut-off not known. Bank at the head of the

lake is the same elevation as the present river bank, and said to be above overflow. Head of the lake is about 3 miles from the river.

Eagle Lake, Terrapin Neck Cut-off.—Made in 1866. General elevations of bank is the same as that of present river bank. Land said to be above overflow. The head of the lake is 7 miles from the present river at the cut off.

Yazoo Lake, at the mouth of Yazoo River.—Said to have been cut off in 1699. Land at the head of the lake has the same elevation as the adjacent river banks. Head of lake is 7 miles from river.

Palmyra Lake, Davis Cut-off.—Made in 1867. Land at the head of the lake is the same elevation as the adjacent river banks. The levels are not well checked and the elevations may be erroneous. Head of the old bend is 7 miles from the river at the cut-off.

Lake Saint Joseph, Hard Times Bend.—Date of cut-off not known. It was probably made long before the Mississippi valley was settled. Elevations at head of lake towards the upper end are about 2 feet higher than adjacent river banks around Hard Times Bend. This part of the lake lies very near Palmyra Lake, and the bank elevations are the same as those of the latter lake. Hard Times Bend lies so far downstream from the part of the lake considered that lower elevations should be expected. The level notes around this lake are doubtful. The head of lake from present river is about 6 miles distant.

Lake Bruin, near Bondurant Landing.—Date of cut-off not known. No elevations are given at the head of the lake on the bend side. Elevations on the point side and the other elevations given are lower than the adjacent river banks. The head of the lake is 6 miles from present river.

Lake Saint John, opposite Fairchild's Bend.—Date of cut-off not known. The land around the head of the lake is about the same elevation as the adjacent river banks. The old bend is about 3½ miles from the present river bank.

Lake Concordia, above Natchez.—Has probably been cut off twice, date not known. At present rate of caving in Giles Bend another cut-off is threatened in the same locality. The land around old river is 5 to 7 feet higher than the concave bank of Marengo Bend, but this is undoubtedly on account of the rapid caving (220 feet per year during the past 70 years), which has prevented the deposit from keeping pace with it. The new-made land on the point opposite is as high as the highest land around the old bend.

To farther illustrate the effect of a cut-off, take an ideal case. We know that the river banks have a slope about equivalent to that of the water surface or about 0.3 foot per mile. Then if the elevation of the bank at the upper end of the cut-off is 100 feet we can interpolate the other elevations around the old bend.

The land from the river banks back, has a slope of several feet per mile. Hence it is evident that in consequence of this slope the land at the head of the lake is above overflow, even though it be no higher than the river banks proper.

Measuring around the old bend the distance is 15 miles with a total fall of 4.5 feet, or 2.2 feet per mile if measured through the cut-off. This excessive slope will eventually adjust itself by erosion of banks and bed, but for some time after the cut-off the banks immediately below the cut-off will be overflowed at a comparatively low stage while the banks above the cut-off are above overflow. Under normal conditions the bank at the lower end of cut-off would have an elevation of 99.1 feet instead of 95.2. An examination of the old cut-offs suggests that this difference has been eliminated by deposit below the cut-off.

It is also evident that in the cases examined the old and new river banks have nearly the same elevations, and consequently that the floods of late years do not differ materially in elevation from those occurring before the valley was settled.

CHANGES IN BANK LINE AND SECTION.

The later surveys afford a good opportunity of ascertaining the character and extent of the changes which have taken place since the surveys of 1879–'80. The data available at present embraces the portions of the river lying between Island No. 1 and Scanlan's Landing, Arkansas, and Commerce Cut-off and Saint Louis Landing.

Maps are submitted herewith, which show the changes in shore line and the location of sections compared. The shore-line on the bar side changes so rapidly with slight differences of stage of river, that a comparison of that side has generally been omitted.

Sections have been plotted which are nearly coincident in the two surveys, and therefore show the changes that have occurred in depth and form of section. In plotting, the bottom has been referred to the same plane, and the differences in the water surfaces show the difference in the stages at which the soundings were taken.

These comparisons are of peculiar interest as showing to some extent the effect of the great floods which have occurred in the interval between the two surveys.

CAVING BANKS.

unt of caving shown on the accompanying sheets was determined by the distance between the positions of the bank lines as located by the two

al points on which these two surveys depend are sometimes 3 or 4 miles there may be a slight difference in sketching between the intermediate ted with the stadia; hence the figures given must not be regarded as exact al case. As a whole they may be considered as very near the truth. Where has been very slight the comparisons fail to show it.
l, the advance of the bars into the bends has kept pace with the receding

unt and rate of caving is given in tabular form for the principal bends. test caving is most frequently found near the lower end of the bend, it fol- he present tendency is to make the river more nearly straight.
nd No. 1 to Island No. 10 the caving banks aggregate 209,850 feet in length e of 55 miles, or an average of 3,816 feet per mile of river. The heaviest rs in Puntney and Beckwith bends and near Island No. 10. The amounts t different points are given in detail on sheets 1, 2, and 3 of the published npanying this report.
utbersville to head of Frame's Chute the caving banks aggregate 502,000 th in a distance of 115 miles, or an average of 4,365 feet per mile of river. t caving is above Rucker's Point, Forked Deer Island and opposite bend, oint and above Centennial cut-off. At Forked Deer Island it has caved 4 years.
nmerce Cut-off to Saint Louis Landing the caving banks aggregate 392,520 th in a distance of 77 miles, or an average of 5,098 feet per mile of river. t caving is near Commerce Cut-off, in Bordeaux Chute, above Hardin's rotter's Landing, and Jackson's Point. Near the lower end of Bordeaux ntire river moved west a distance of 5,000 feet from 1880 to 1883, or at the ut 1,670 feet per year.
r's Landing the caving from 1878 to 1883 amounted to 1,560 feet. From the caving along Helena Island amounted to 1,310 feet, while from 1880 caving was very slight.
of Shoo-Fly Bar has moved down-stream over half a mile in spite of the was largely composed of gravel.
Tow-head, the tow-heads just below O. K. Landing, and a large portion of Tow-head have been washed away.
. 65, which in 1881 was 1¼ miles long and ¼ mile wide, and covered with er, has entirely disappeared.
noticed that the greatest changes have taken place on the last-named ear the cut-offs at Commerce and Bordeaux Chute.
e 60 feet as the distance from the top of the bank to the bottom of the l average something more than that) along caving bends, and use the mean widths given in the accompanying plats we can compute the number rds moved by erosion of banks.
nd No. 1 to Island No. 10 it is found to be 551,385 cubic yards per annum le of river.
uthersville to Frame's Chute, 999,041 cubic yards.
nmerce Cut-off to Saint Louis Landing, 2,231,726 cubic yards. The latter tow-heads and Island 65, which have been washed away.

CAVING BANKS.

Locality.	Length.	Maximum width of erosion.	Mean width.	Annual rate of erosion.
	Feet.	*Feet.*	*Feet.*	*Feet.*
l	20,000	720	350	87
	35,000	620	266	67
Bend	20,500	260	140	40
d	20,600	1,020	511	137
d	11,000	395	148	40
Bend	23,300	260	170	48
l	20,000	787	502	136
Bend	31,300	729	377	75
ling	10,300	1,149	681	137
t	15,000	3,100	1,085	217
t to Ruddle's Point	28,750	623	356	71
Bend	28,000	720	371	74
Bend	22,700	970	666	183

CAVING BANKS—Continued.

Locality.	Length.	Maximum width of erosion.	Mean width.	Annual rate of erosion.
	Feet.	*Feet.*	*Feet.*	*Feet.*
Reelfoot Bend	50,200	870	257	51
Little Prairie Bend	25,000	1,641	761	150
Booth's Bend	15,000	190	169	44
Coleman's Bend	28,100	500	327	[illegible]
Needham's Bend	33,300	790	395	106
Barfield Bend	37,600	990	370	100
Forked Deer Island	23,000	2,210	862	230
Canadian Reach	16,000	1,670	996	373
Ashport Bend	19,000	600	344	94
Elmot Bend	13,400	760	206	56
Craighead Point	11,900	560	288	78
Morgan's Point	11,000	900	501	127
Idaho Bend	54,300	1,040	241	90
Bateman's Bend	26,000	1,229	589	147
Centennial Bend	21,000	1,670	549	149
Fogleman Chute (both sides)	15,600	330	168	82
Beef Island	11,000	767	478	151
Bradley's Bend	13,300	460	287	65
Redman's Bend	16,000	628	310	65
Commerce Cut-off (partial)	8,850	2,950	[illegible]	820
Ashley Point	15,000	700	565	190
Brinkley Bend	23,100	2,460	798	263
Bordeaux Chute	13,800	4,300	1,343	447
Hardin's Point	18,900	1,160	418	130
Ship Island Bend	8,420	880	445	146
Harbert's Bend	20,000	210	148	40
Shoo Fly Bend	8,100	1,450	830	277
Hopefield Bend	11,700	1,480	690	104
St. Francis Bend	36,200	580	287	66
Trotter's Bend	19,000	1,700	1,220	407
Helena Bend	19,000	670	433	144
Montezuma Bend	18,600	500	307	60
Delta Bend	8,500	360	187	88
Horse Shoe Bend	16,700	420	288	94
Old Town Bend	20,000	530	270	80
Island 63	9,000	460	210	70
Hughey's	15,000	528	315	105
Island 64 Bend	15,000	700	345	113
Ludlow's Bend	36,000	400	301	100

CHANGES IN SECTION.

A careful analysis of the sections compared gives the following results:

Character of changes in river.	Island No. 1 to Island No. 10.	Caruthersville to Frame's Chute.	Commerce to Saint Louis Landing.	Total.
Narrower and deeper	18	30	26	74
Wider and deeper	[illegible]	38	5	[illegible]
Same width and deeper	5	5	7	17
Narrower and same depth		6	3	[illegible]
Wider and same depth	3	5	4	12
Same width and same depth		[illegible]	1	6
Same depth or deeper (total)				121
Narrower and shallower	6	8	9	[illegible]
Wider and shallower	4	24	17	[illegible]
Same width and shallower	6	[illegible]	3	[illegible]
Shallower (total)				[illegible]

It will be seen from the above table that, out of the 251 sections compared, the last survey shows that the river is the same depth or deeper in 171 cases and shallower in 80 cases. It is the same width in 35 cases, narrower in 106 cases, and wider in 110 cases. In the vicinity of the improvements at Plum Point, say from Island 25 to Randolph, the sections show the same depth or deeper in 34 cases, and shallower in 10 cases. The increase in width in this reach is quite marked. The river is wider in 28 sections, narrower in 10 sections, and same width in 6 sections. The increase in depth occurs mainly in the bends and the decrease on the crossings. The greatest erosion of the river bed does not occur where the bank erosion is the greatest, but where the banks have been stable, or the channel contracted. A section near Hardin's Point has decreased in width 4,900 feet and increased in depth 45 feet. The effect of the stable banks near Columbus and Hickman has been a very decided increase in depth.

As a rule, decrease in width is accompanied by a corresponding increase in depth, and conversely, an increase in width shows a decrease in depth.

In the bends below Friar's Point, where is a great difference in the stages of the sections, it will be seen that the deepest sections belong to the highest stage. That is, the bottom seems to have been scoured out during the high stage or filled at the lower stage. Many of the sections show but little change.

Very respectfully, your obedient servant,

J. A. OCKERSON,
United States Assistant Engineer.

First Lieut. SMITH S. LEACH,
Secretary Mississippi River Commission.

2.—*Report of Assistant Engineer C. M. Winchell, Island No. 1 to Donaldson's Point.*

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., June 1, 1884.

SIR: I have the honor to submit herewith a report concerning the field operations of the topographic party under my direction during the season of 1883-'84.

In obedience to your instructions I left Saint Louis on the evening of October 10, 1883, with the party, consisting of 10 assistant engineers, 2 recorders, 6 rodmen, 8 stadia men, 6 boatmen, 16 axmen, 1 steward, 2 cooks, 3 waiters, 1 watchman, and a tug crew of 3. We reached Cairo, Ill., and went on board the quarter-boats Tennessee and Pioneer on the morning of October 11. After taking on supplies at Cairo, the quarter-boats were towed to Island No. 1 by the iron launch which had been assigned to the party, and work was begun October 12. Assistant J. A. Paige, G. W. Wood, H. W. Kerr, F. B. Maltby, and G. H. French were assigned to topography; Assistant Moses Greenwood, hydrography; Assistants L. C. Jones and J. W. Dorst, levels; Assistant G. H. Whitney, office work, platting field notes of the survey; Recorder D. E. Perkins and C. K. Tharp read sextant angles and recorded in the sounding-boat.

The upper limit of our survey joined the lower limit of the topographic survey made in 1876-'77 by the U. S. Lake Survey under the direction of General C. B. Comstock, and it was intended to continue the same down the river to Caruthersville, Mo., but owing to lack of funds to carry on the work, the party was called in and disbanded December 1, at which time the survey had been completed to a point about 5¼ miles above New Madrid, Mo., 45 miles above Caruthersville.

TOPOGRAPHY.

In addition to the usual limits of the survey, the line of bluffs was located by compass line from Island No. 1 to Reelfoot Lake and frequent determinations made of the difference of elevation between the top and bottom of the bluffs. Their height above the water surface of the river at medium stage ranges from 150 feet to 200 feet.

All of the lakes, ponds, and bayous between the bluffs and the river were surveyed by compass and stadia. Connections were made with two county lines in Kentucky, and three points on the State line between Tennessee and Kentucky. Several township and section corners of the United States land survey were also connected with this survey. Obion Creek, Bayou du Chien, and James Bayou were meandered from 2 to 5 miles beyond the prescribed limits of topography.

Assistant French made a survey of the head of Reelfoot Lake and about 7 miles of its length. In the report of the commissioners appointed by the States of Kentucky and Tennessee to locate and mark the boundary line between those two States, it is stated that it took them six weeks to run a line across Reelfoot Lake, "a feat never before accomplished," the obstacles being numerous sloughs, swamps, bayous, cane brakes, &c. Mr. French was only two weeks in crossing the lake and surveying both

shores by independent lines, it being impossible to locate one shore by intersections from the other, on account of dead trees in the lake and marsh grass along the shores. The State commissioners measured their distances with a chain. Mr. French used a compass and stadias.

The supposition that Reelfoot Lake was once the channel of the Mississippi River, is, in my opinion, without foundation in fact. It has none of the characteristic features of "old river" lakes, but is like the "sunk lands" of the Saint Francis Basin, very irregular in shape, shallow, and full of dead trees standing in the water. It is 5 feet to 12 feet deep, except in two places, where it is 20 feet deep. It was probably a cypress swamp which sank during the earthquake convulsions of 1811.

HYDROGRAPHY.

Sections were sounded about 350 meters apart and a longitudinal line sounded along the thread of deepest water over the entire reach of river surveyed.

The maximum depth found was 142 feet, and this depth was found both at Columbus and Hickman. At Hickman the river is very narrow, the wet section being not more than half as wide as it was at the same stage in 1879, but the depth has more than doubled in the same time. The narrowest place found was at Chalk Bank, where the gravel and sand bar projects from Wolf Island to within 275 meters of the opposite bank. Here, as at Hickman, the rocks at the base of the bluffs project some distance into the river and are from 3 feet to 15 feet below the surface at low stages.

LEVELS.

Several new permanent bench-marks were established, and at each stone line a river crossing was made with two instruments by simultaneous observations, and duplicate lines of levels carried from the crossing hubs to the B. M's. on the stone line. A continuous line of levels was run on the left bank checking in the precise level bench-marks which had previously been established.

CAVING BANKS.

No very marked changes have taken place in this part of the river since 1879. The caving in the bends has been continuous, but not very rapid, the greatest amount of cutting being at Parker's, above Hickman, where it reached a maximum of 274 meters in four years, and just below Slough Landing, in Missouri Bend, where it has caved 240 meters. Immediately above Hickman, at Bayou du Chien, it has caved 89 meters since 1879.

Résumé.

Miles of river surveyed	55
Square miles topography	136
Square miles hydrography	38
Total area surveyed	174
River crossings of levels	17
Cross-sections sounded	262

SLOPE TABLE.

Locality.	Distance.	Slope per mile.	Rising or falling.*	Cairo gauge-reading.
	Miles.	*Feet.*		*Feet.*
Island No. 1 to Columbus	11	0.16	±	9.97
Columbus to foot of Wolf Island	7	0.46	—	10.40
Foot Wolf Island to Salmon's Landing	7	0.34	+	12.40
Salmon's Landing to James' Bayou	11	0.28	±	20.38
James' Bayou to △ Birdsall	10	0.31	±	22.06
△ Birdsall to △ Everett	11	0.35	+	26.30
Mean slope for entire reach	57	0.32		

* + = rising; — = falling; ± = stationary.

I cannot too highly commend the diligence and skill of my assistants, upon whose zeal the favorable progress of the work so largely depends.

Very respectfully, your obedient servant,

C. M. WINCHELL,
Assistant Engineer.

First Lieut. SMITH S. LEACH,
Secretary Mississippi River Commission.

3.—*Report of Assistant Engineer L. L. Wheeler, Caruthersville, Mo., to Randolph Point, Tennessee.*

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., August 1, 1884.

SIR: I have the honor to submit the following report upon the operations of the party in my charge during the season of 1883–'84.

The work assigned to the party was to make a topographical and hydrographical survey of that section of the Mississippi River between Caruthersville, Mo., and Randolph Point, Tennessee. The organization of the party was as follows: Chief of party, L. L. Wheeler; topographers, A. N. Darrow, O. W. Ferguson, E. E. Haskell, O. A. Orrman, A. H. Weber, J. W. Payne; hydrographers, H. B. Wood, Fred. Morley; levelers, A. E. Kastl, T. C. Thomas; draughtsman, A. Perrilliat; and 48 men.

In accordance with your instructions, the party left Saint Louis by rail the evening of October 10, and went on board the quarter-boats Illinois and Kentucky, at Cairo, Ill., the following morning. The boats were taken in tow the same day by the United States steamer Patrol, and reached Caruthersville the evening of October 13. Field work commenced Monday, October 15, on a line normal to the river at Caruthersville, and continued without interruptions of any kind until about January 1, when the weather became very inclement, and continued so until the end of the season. At the above date Brandywine Island had been reached, and the work remaining to be completed included Centennial and Brandywine Islands, Islands 37 and 39, and the main banks down to Randolph Point. The river at this time was rising fast and rapidly covering the low bars and islands, and bringing down large quantities of driftwood. The weather became intensely cold and a large portion of the time heavy fogs hung over the river, making it difficult to see signals or to do field work of any kind in the immediate vicinity of the river. The work was pushed down the main channel as fast as the weather would permit, and, January 5, was completed in and along the main channel to Randolph Point. The Patrol moved the party, January 6, to Viola Landing in the old river, behind Centennial Island. A heavy snow-storm set in the next day and ice commenced running the same evening. From that time until the end of the work the river was not free from ice, so that no hydrography could be done. The work on the main bank behind Centennial Island and Island 37 was completed by the parties walking to and from work through snow from 6 to 8 inches deep, part of the work being done on the ice. The Patrol returned to the party the evening of January 9, and remained until the morning of January 12, when finding it impossible to continue work and provisions being exhausted the party was disbanded and taken to Memphis by the Patrol. The work left unfinished includes the whole of Island 37 and that portion of Centennial Island lying outside of the old main bank, and the hydrography in the chutes behind these islands. The total number of days spent in the field was 94, of which 4 were spent in traveling, 2 were observed as holidays, 13 were Sundays, and 5 were too stormy for work, leaving 70 days in which work was done. The length of main river surveyed was 101 miles, the average daily progress being 1.07 miles or 1.44 miles per working day. The average daily progress in miles of river was very much diminished by the number of large islands to be surveyed. The total number of square miles of topography was 274, and of hydrography 80, making the total number of square miles surveyed 354, being a daily average of 3.76 square miles, or 5.05 square miles per working day.

TOPOGRAPHY.

A preliminary survey of this portion of the river had been made during the season of 1879–'80, and the work of last season was intended to fill in the topographical details.

It was found, however, that in consequence of the loss of many of the triangulation stations and of the necessity of running shore lines to locate sounding stations and to determine changes in banks, bars, &c., that a complete survey was necessary. This work did not differ in detail from what had been done previous seasons. A sufficient number of triangulation stations were found to furnish azimuth, and to check stadia distances. Of the 100 triangulation stations on this portion of the river, 54 have been lost by caving of the banks, 2 have been taken away by persons unknown, 3 have been broken, and 2 were not found, although at safe distances from the river.

HYDROGRAPHY.

The instructions required that the sections sounded in 1879–'80 should be resounded as nearly as they could be identified. It was found, however, that, on account of changes that had taken place in banks, bars, islands, tow-heads, &c., the old sections could not be identified, and could be found only by plotting the shore-lines and comparing the two surveys. To have done this would have kept the hydrography far behind the other work, which it was not advisable to do. In the 101 miles of

main river 503 sections were sounded, making the average distance between them 323 meters. Probably none of the old sections would be more than 200 meters from one of the new ones, and the majority of them would be much less. It is probable that, on account of the changes that have taken place, the positions of the old sections relative to the general outline of the river had changed by as great distances, and that, therefore, the old sections have been as nearly duplicated as if sounded in exactly the same positions.

The following is a summary of the hydrographical work:

Miles of main river	101
Square miles	80
Sections in main river	503
Sections in chutes, &c	121
Soundings	29,283
Sextant angles	16,974

LEVELS.

Elevations were based upon a line of precise bench-marks, and are referred to the Memphis datum plane. There had been set originally 27 bench-marks, and of these 21 were found in good condition, 3 were not found but probably are safe, 1 had caved in the river, 1 had been broken, and 1 had been taken to serve as hearth-stone in a cabin near by.

The following table shows the discrepancies between the results of the precise levels and the ordinary levels:

Bench-marks.	Distance.	Discrepancy.	Bench-marks.	Distance.	Discrepancy.
	Miles.	*Feet.*		*Miles.*	*Feet.*
No. 27 to No. 28	3¾	−0.084	No. 42 to No. 43	½	+0.027
No. 28 to No. 31	14	−0.018	No. 43 to No. 44	2¼	−0.121
No. 28 to No. 32	17¼	+0.121	No. 44 to No. 45	1½	+0.098
No. 32 to No. 33	2	+0.118	No. 45 to No. 46	2	−0.052
No. 32 to No. 37	19¼	+0.097	No. 48 to No. 49	4	+0.070
No. 37 to No. 38	4¼	+0.011	No. 49 to No. 51	4	+0.062
No. 37 to No. 39	8¾	+0.063	No. 51 to No. 52*	8¼	−0.098
No. 39 to No. 41	9½	−0.078	No. 51 to No. 53	8¾	−0.146
No. 41 to No. 42	4	+0.008			

* No. 52 said to have been disturbed by a falling tree.

Lines of levels were run on each bank, the two checking each other by river crossings and by comparisons of water surfaces. The following table shows the discrepancies between the two lines of ordinary levels:

Locality of comparison.	Distance.	Discrepancy.	Locality of comparison.	Distance.	Discrepancy.
	Miles.	*Feet.*		*Miles.*	*Feet.*
Booth's Point, Tennessee	7½	+0.327	Morgan's Point, Arkansas	9½	+0.030
Foot of Island 21	14	−0.111	Andrew's Landing, Arkansas	15	+0.037
Daniel's Point, Arkansas	20¾	+0.117	Brandywine Island	10½	+0.179
Elmot Landing, Arkansas	8½	−0.034			
Fulton, Tenn	14¼	−0.020			

There have been set along the section of the river 116 stone line bench-marks, of which 14 were set during last season. Of the 102 bench-marks set in 1879–'80 5 have been lost by caving of the banks, 3 have been broken, and 8 were not found, although at safe distances from the river. Filed herewith is a table showing all elevations of stone line bench-marks determined, and discrepancies where elevations have been obtained in both seasons for the same bench-marks. The elevations of bench-marks used in determining the low-water slope of 1883 were determined, and the water-gauges at Cottonwood Point and Fulton inspected, and the elevation of their zeros determined.

The assistants performed their duties with ability and energy, and to them is largely due the rapid progress of the work.

Very respectfully, your obedient servant,

L. L. WHEELER,
Assistant Engineer.

First Lieut. SMITH S. LEACH,
Secretary Mississippi River Commission.

APPENDIX D.

REPORT UPON AND RESULTS OF EXPERIMENTAL WORK AT VARIOUS DISCHARGE STATIONS.

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., October 20, 1884.

GENERAL: I have the honor to submit herewith the results of the experimental work done at the Paducah, Columbus, Helena, Hays' Landing, and Red River Landing discharge stations in 1882. The work related mainly to the distribution of velocities throughout the cross-section.

The original reports are voluminous and contain much detail of computation not essential to a complete presentation of the results. The important parts have therefore been extracted; but it should be added that *every individual result* is presented in figures, and the individual curves omitted may easily be reconstructed from them by any one so inclined.

The methods of reduction are described in the report accompanying the Paducah results, and were the same for all the stations, all the computers working from one memorandum and under the same supervision. All the work was done with current meters.

There are given for each discharge section tables showing the ratings of meters used in determining velocities, and tables showing depths, velocities at each tenth of depth for each observation, means for each station, means of all stations, and means of all observations. For Paducah and Red River Landing there are given reports upon the reductions by Assistant Engineer E. H. Twining. A table is given showing transverse distribution of velocities observed at seven feet beneath the surface in the bend above Columbus. There are also given tables showing areas of a section in Beckwith's Bend, 12 miles below Columbus, and of a section in Brunette Bend, 22 miles below Red River Landing.

For each section a plate is given showing a sketch of the locality, the general shape of the cross-section and the vertical velocity curves. In order to economize space the origins of velocities in the curves have been so taken as to bring the curves as near each other as possible without confusion. The scales for velocities and depths are uniform throughout.

There is also given a plate showing the curves representing equal velocities at the Hays' Landing section at low water, the stage being between 6 and 7 feet. Each of the velocities there shown, is the mean of 23 observations made on separate days, the river being practically at a stand.

While the curves of each station seem to have a different characteristic form, they are in close accord on one very important point in practical gauging, viz:—the depth at which the mean velocity is to be found. The final table shows the grand mean curve for all localities and the percentage of the depth at which mean velocity is found in the mean curve for each locality.

This percentage varies from .60 to .71 only.

Very respectfully, your obedient servant,

SMITH S. LEACH,
First Lieutenant of Engineers, Secretary.

General C. B. COMSTOCK,
President Mississippi River Commission, and
Chairman Committee on Surveys and Examinations.

1.—PADUCAH, KENTUCKY.

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., July 6, 1884.

SIR: In accordance with instructions, I have the honor to submit a report on the reduction of experimental work performed by Assistant W. G. Price, in the year 1882, at the Ohio River discharge section near Paducah, Ky.

The section is situated 3 miles below the mouth of the Tennessee River, and about 15 miles below the mouth of the Cumberland. The effect of local changes in these rivers is at times noticeable at the section, in producing irregularities both in amount

and distribution of velocities, especially at the lower stages. In general, however a rise of these rivers is so nearly coincident with a like movement of the Ohio, that their effect is lost in the mass of the main river.

A middle bar, just showing at extreme low water, lies at about two-thirds the width of the river from the Kentucky shore. Nearly opposite the head of this, and nearer the Kentucky side, is the foot of a series of shoals, which are virtually a continuation of the point of land between the Ohio and Tennessee. Between these and the bar first mentioned is the high-water channel of the Ohio. The effect of this conformation will be alluded to in the course of the report.

A sketch of the locality is appended.

The experimental work included the following particulars: Determination of velocities in vertical planes; comparison of mid-depth and integration velocities; comparison of rod-float and meter velocities; current oscillations; meter ratings.

Vertical velocities.—These were all taken with the meter, Ellis No. 6 being used up to January 24, and Price A after that date. Observations were made at 17 stations, except from July 14 to August 31, when the number of stations was 16. These stations were located by fixed signals, so that the points of observation were nearly invariable. Only during the period above mentioned was it found necessary to redistribute the observations, in the process of combination. The meter was run for one minute at every foot in depth (in very shoal water at one-half foot intervals), and a mid-depth run of five minutes was made before and after each vertical. The whole number of verticals is 211.

The results are tabulated in the annexed sheets, numbered 1 to 84, with a graphic view of each vertical and of its location on the section. The meter registrations are given for one-minute runs, and the velocities in feet per second. Except where otherwise stated the scale of depth for the plotted curves is 10 feet, and that of velocity 1 foot to the division. In the location the scale is 1,000 feet to the division horizontal; the vertical scale is arbitrary.*

Upon the assumption that the velocities at proportionate depths, at all stations, maintain a fixed ratio, the vertical curves were divided into tenths, from surface to bottom, and the velocity at each tenth measured or computed, thus forming a new series of verticals of 11 points each. The verticals of this series were combined according to their respective stations, the mean of each group (station mean) representing the normal distribution of velocities in a vertical plane for that station. The station means were in like manner combined, the result (means of stations) giving the vertical distribution of velocities for the whole section. A grand mean was obtained by combining all the numbers of the series, without distributing them to their respective stations. This differs slightly from the mean of stations, from the fact that the number of observations was not the same for all stations, those made at the higher stages of water not always including every station on the section.

Inspection of the curves on sheet No. 84 shows considerable variation in form, in passing from No. 1, on the Kentucky side, to No. 17, on the Illinois side, those on the left side of the middle bar having their maximum below, and those on the other side at the surface. In connection with the grand mean curve, the mean of stations 1 to 8, and that of stations 9 to 17, are exhibited. The difference in form arises from the fact that, as previously explained, the river at this point does not present a homogeneous section. Because of the disturbances from this source, it is hardly to be expected that the grand mean curves should be capable of being expressed by an equation. The nearest approach is apparently to that of an ellipse with its major axis vertical. Mr. Price is probably right in attributing some of these irregularities in the vertical distribution of velocities to differences in temperature of the two rivers, although, no record of the temperature of the water having been kept, the extent of this influence cannot be certainly defined. Aside from this, however, the variations in relative stage of the Ohio and its affluent affect to some extent the distribution of velocities, both vertical and transverse. Furthermore a change in transverse distribution also occurs as the absolute stage becomes lower, the maximum velocity above the 8-foot stage being on the Kentucky side, and below that stage on the Illinois side, except in case of a transient rise in the Tennessee. This apparently results from the action of the bar just above the section, which at low water tends to restrict the Ohio current to the north channel.

Mid-depth and integration velocities.—These experiments, 75 in number, were all made after the river had fallen to the 25-foot stage. The meter was run at mid-depth for five minutes, the registrations being noted at intervals of fifteen seconds; the integrations (taken from bottom to top only) were also recorded every fifteen seconds. Only mid-depth velocities were plotted, and the mean compared with that of the integrations. Inspection of the curves shows that the variations from the mean, with few exceptions, lie within the limits of error in observation, viz, a half second of time and

* The tables here referred to are not published.

a half registration, and that there is little evidence of anything like rhythmic pulsation in the current during the time (five minutes) given to the observation.

The sum of the two errors mentioned gives an absolute error which may occur in any observation, and which will show a larger percentage as the velocity is lower. The mean of velocities observed at all stations for the period of this set of observations is 2.16 feet per second; the possible error is 0.14, or 6.5 per cent.

The average of all the observations gives a departure from the mean of ± 6.5 per cent.; this however varies widely in the individual observations, ranging from 2 to 20 per cent. There are evidently, besides the errors of experiment, causes of fluctuation to be sought for in the irregularities of the stream lines and in the management of the meter. It is manifest that, if the meter is free to swing as a whole, like a pendulum, lateral variations will produce oscillations, which, interfering with the current movement, will give velocities varying from one another in the same way, and for the same reasons, as upward and downward integrations vary. These movements of the meter mask to some extent the current variations, and must be as far as possible eliminated before the latter can be examined. From the experiments on current oscillations at this station, it appears that lateral deviations are very small, and it would seem that the disturbing causes must be sought for in real changes of velocity, from instant to instant, at the point of measurement. An epicyclical movement of the particles of water, such as theoretical considerations would indicate, of course implies momentary changes in velocity at any given point. The extent of these and their regularity of recurrence can only be determined by means of an apparatus of continuous record, to avoid those sharp irregularities which must appear in any series of detached observations.

In order to compare roughly the fluctuations in mid-depth with those of the vertical velocities of the same period, a free-hand curve was drawn through each vertical, approaching as nearly as possible the form of the mean vertical curve of the section; the half sum of the extreme variations from this line was considered as the $\pm$ departure for that observation. The mean obtained in this way is 5 per cent., varying in individual cases from 2 to 15 per cent. of the mean velocity. In this case the time and registration errors have but one-fourth the weight of those in the mid-depth observations, since in the verticals the meter is recorded at one-minute intervals.

On the assumption that the errors of observation do not exceed the necesssary amount stated (a half registration and a half second) these results indicate the action of a disturbing cause in the movements of the water. It is found, moreover, that the greatest fluctuations occur at the ends of the section, where the effect of the shore slope is felt. In the case of the verticals, it is not possible, in the absence of repeated observations at the same time, to decide how far the lowest observed velocity is affected by the bottom of the river, though the variety in form of the individual curves in this part points to a considerable range of variation in velocity.

The comparison of mid-depth and mean integration velocities shows that the former are about 3 per cent. in excess of the latter—a little more than this, if the mean of up and down integrations be taken, since the upward regularly exceeds the downward mean by 1 or 2 per cent. This agrees closely with the results of observations in vertical planes, in which the mean coefficient for the reduction of mid-depth to mean velocity is 0.965, varying, however, for the various stations from 0.944 to 1.000, and for the two sides of the river from 0.955 (stations 1 to 8) to 0.975 (stations 9 to 17), this difference between the two groups of stations proceeding from the relatively low surface velocity on the Kentucky side, as noticed above.

This coincidence incidentally confirms the correctness of the presupposition on which most of the meter work on the Mississippi River and tributaries is based, viz, that the integrations furnish the true mean of velocities past a vertical.

Rod-float and meter velocities.—Rod floats were run in connection with the meter on twenty-four days, from June 7 to the end of the season; six floats were run at each station, and the mean taken. These velocities have been tabulated, but are not presented here, as the details add but little to the general results contained in the tables of discharge observations, Report Mississippi River Commission 1883, pp. 185 ff. Plotted transverse curves of eight days' observations are, however, given on page 85, and ratios of meter to rod-float velocities on page 86.

In general, it will be seen that the velocities obtained by rod-floats are lower than indicated by the meter, for stages below 25 feet on the gauge. The few simultaneous observations made above this stage indicate that the rod-floats give at higher stages a slightly greater velocity than the meter, owing probably to the immersion. In the absence of slope data, no satisfactory comparison can be made of velocities observed from January 27 to February 10, when rod-floats alone were used, with those found later by the meter, at like stages. The mean ratio for stages from 3.23, to 10.40 is 0.946; from 3.23 to 20.88, 0.949; from 3.23 to 31.36, 0.963.

It was expected that comparisons could be made between the rod-float velocities and those found by the meter, at the same stage, down to the depth of immersion,

but it was found that changes in slope made this comparison very uncertain. On two days rods were run at varying depths, and at the same time vertical velocities taken with the meter, as follows:

Date.	Station.	Depth.	Immersion.	Velocity.		
				Rod-float.		Meter to immersion depth.
				Observed.	Reduced.	
1882.		Feet.	Feet.			
September 28	4	25	9.2	2.01	1.85	2.02
			16.1	1.98	1.87	2.01
			21.4	1.92	1.86	1.95
October 4	13	11.2	4.8	2.16	2.00	2.30
			9.2	2.10	2.02	2.22
October 4	14	11.0	4.8	2.33	2.15	2.33
			9.2	2.21	2.13	2.17
October 4	15	12.5	4.8	2.24	2.06	2.29
			9.2	2.17	2.07	2.19
November 1	16	10.8	4.2	1.45	1.34	
			9.2	1.36	1.32	

These results, so far as they go, show a tolerably close agreement of rod-float and meter, down to immersion depth; the coincidence also of the rod-float velocities reduced (by Francis formula) tends to verify this formula for large streams. It may be observed, moreover, that the velocities obtained by rods and meters respectively approximate more nearly if, in the case of the latter, account is taken of the fillet (in these observations 1 foot) of water next the bottom, not reached by the meter this having more weight in determining the mean velocity as the depth of water is less. From an estimate of the rate of decrease in velocity in approaching the bottom, based on the form of the mean-velocity curve, it would appear that the mean velocity of this fillet is not less than 85 per cent. of the velocity at 1 foot above the bottom.

Current oscillations.—Experiments were made to detect the occurrence of lateral deflections in the thread of the current at different points, by means of a submerged vane. These at first, when the whole apparatus was free to swing, indicated some oscillations; but when lateral guy lines were used to prevent this swinging, the deflections disappeared or were reduced to a very inconsiderable amount.

Meter ratings.—The meters rated were Ellis No. 6, Herschel No. 12, and Price A. A table of results is appended, as also the plotted ratings of meter A. The close correspondence of the different ratings of the last-named meter, and the absence of any important variations in its registering, show that it is to be relied on at all velocities.

Very respectfully, your obedient servant,

E. H. TWINING.

First Lieut. SMITH S. LEACH,
Secretary Mississippi River Commission.

Ratings of meters used at Paducah, Ky.

Locality.	Date.	Meter.	Number of observations	Registrations per revolution	a	b	Range of velocities per second	Where taken.
	1882.						Feet	
Paducah, Ky	Feb. 23	Price A	15	2	0.027	0.511	2.04–5.68	In a pond.
Do.	Mar 4	do	13	2	0.028	0.200	1.40–9.56	Do.
Do	Apr 12	do	13	2	0.0284	0.140	1.07–6.96	Do.
Do	Apr. 26	do	8	2	0.0289	0.414	2.04–9.09	Do.
Do*	Apr 26	do	8	2	0.0282	0.152	1.52–9.09	Do.
Do	June 21	do	10	2	0.0262	0.154	1.25–8.00	Do.
Do†	June 21	do	11	2	0.03175	0.158	1.03–7.14	Do.
Do.	July 26	do	17	2	0.0317	0.154	0.98–7.13	Do.
Do	Sept 27	do	18	2	0.03165	0.150	0.70–6.76	Do.
Do.	Feb. 4	Herschel No. 12	22	1	0.00748	0.011	1.39–9.15	Do.
	1881.							
Saint Louis, Mo	Nov 8	Ellis No. 6	....	1	0.0632	0.110	....	In reservoir
	1882.							
Paducah, Ky‡	May 2	do	6	1	0.056	0.205	2.30–8.00	In a pond
Do§	May 2	do	5	1	0.0627	0.121	2.01–5.32	Do.

* With new weight. † With new wheel. ‡ With weight § Without weight.

Velocities in feet per second at each tenth of depth as resulting from the velocity observations made at Paducah, Ky., in 1882.

STATION 1.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom
14	1.50	1.50	1.53	1.55	1.56	1.53	1.43	1.41	1.35	1.27	0.81
15	1.43	1.46	1.52	1.66	1.64	1.66	1.69	1.69	1.51	1.42	1.17
10	1.30	1.30	1.27	1.33	1.30	1.24	1.27	1.27	1.24	1.20	1.05
20	1.84	1.84	1.90	1.76	1.70	1.70	1.63	1.62	1.56	1.51	1.52
13	1.71	1.72	1.80	1.75	1.71	1.70	1.74	1.60	1.54	1.47	1.33
14	1.74	1.76	1.83	1.84	1.79	1.80	1.69	1.70	1.61	1.47	1.27
10	1.58	1.58	1.60	1.59	1.52	1.52	1.46	1.55	1.50	1.33	1.30
16	1.30	1.27	1.28	1.27	1.19	1.26	1.24	1.18	1.24	1.24	1.14
14	1.30	1.27	1.23	1.22	1.25	1.23	1.14	1.14	1.08	1.08	0.83
12	1.17	1.17	1.15	1.16	1.14	1.13	1.06	1.07	1.08	1.04	0.86
10	0.89	0.89	0.90	0.89	0.89	0.83	0.87	0.80	0.79	0.60	0.41
Means=13.4	1.43	1.43	1.46	1.46	1.43	1.42	1.38	1.37	1.32	1.24	1.06

STATION 2.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom
30	1.94	1.96	2.19	2.26	2.19	2.12	2.05	1.76	1.76	1.65	1.20
33	1.91	1.95	2.07	2.10	2.30	2.25	2.05	1.91	1.74	1.44	1.20
22	1.81	1.85	2.01	2.03	1.96	1.93	1.97	1.89	1.77	1.58	1.27
26	2.22	2.25	2.22	2.34	2.25	2.20	2.25	2.06	1.87	1.74	1.49
26	2.03	2.10	2.19	2.26	2.25	2.26	2.19	2.11	1.90	1.78	1.43
23	2.19	2.33	2.26	2.30	2.29	2.25	2.23	2.17	2.01	1.80	1.55
22	2.22	2.22	2.18	2.14	2.07	2.04	2.03	2.00	1.89	1.77	1.46
20	1.90	1.90	1.90	1.87	1.86	1.75	1.59	1.72	1.56	1.43	1.17
19	1.71	1.73	1.78	1.75	1.71	1.74	1.62	1.66	1.58	1.33	1.11
19	1.56	1.58	1.60	1.69	1.53	1.54	1.41	1.37	1.34	1.22	0.98
17	1.49	1.49	1.45	1.45	1.46	1.43	1.34	1.24	1.17	1.20	1.04
Means=23.0	1.91	1.94	1.99	2.02	1.99	1.96	1.90	1.81	1.69	1.54	1.26

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 3.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
57	4.10	4.21	4.32	4.35	4.16	4.07	3.92	3.67	3.39	2.78	2.16
37	2.05	2.22	2.37	2.47	2.45	2.30	2.35	2.26	2.07	1.91	1.37
36	2.41	2.28	2.38	2.32	2.35	2.44	2.41	2.11	2.06	1.91	1.20
25	2.25	2.25	2.03	2.02	1.84	1.98	2.00	1.90	1.58	1.50	1.36
30	2.53	2.66	2.60	2.66	2.75	2.66	2.53	2.34	2.15	2.00	1.71
30	2.44	2.52	2.53	2.57	2.57	2.57	2.52	2.37	2.28	2.27	1.74
27	2.63	2.54	2.60	2.60	2.47	2.47	2.27	2.38	2.15	1.93	1.65
26	2.37	2.30	2.34	2.39	2.41	2.24	2.26	2.17	2.09	1.98	1.71
27	2.57	2.60	2.50	2.53	2.36	2.41	2.37	2.17	2.20	1.94	1.71
23	1.80	2.03	1.97	1.97	2.02	1.90	1.81	1.75	1.69	1.61	1.30
22	1.71	1.65	1.65	1.65	1.64	1.66	1.57	1.52	1.42	1.34	1.11
22	1.65	1.65	1.75	1.72	1.74	1.54	1.49	1.46	1.36	1.37	1.11
Means=30.2	2.38	2.41	2.42	2.44	2.40	2.35	2.29	2.18	2.04	1.88	1.51

STATION 4.

72	6.25	6.30	6.56	5.72	5.91	5.80	6.00	5.27	5.33	5.46	2.81
70	4.58	5.48	4.89	5.32	5.00	5.03	5.00	4.08	4.63	3.16	1.64
43	2.66	2.70	2.60	2.72	2.67	2.78	2.77	2.63	2.48	2.08	1.58
42	2.35	2.33	2.31	2.47	2.48	2.58	2.54	2.35	2.09	2.01	1.53
37	2.70	2.45	2.48	2.53	2.48	2.51	2.65	2.58	2.39	2.19	1.59
27	2.09	2.00	2.17	1.93	2.01	2.00	1.90	1.77	1.76	1.61	1.43
31	2.91	2.85	2.85	2.95	2.95	2.98	2.91	2.69	2.53	2.15	1.90
30	2.57	2.74	2.79	2.79	2.82	2.82	2.84	2.68	2.43	2.27	1.74
25	2.19	2.05	2.20	2.02	2.04	1.96	1.93	1.83	1.73	1.56	1.49
27	2.44	2.41	2.51	2.20	2.30	2.22	2.21	2.06	2.00	1.75	1.49
27	2.41	2.37	2.62	2.52	2.46	2.42	2.36	2.18	2.41	1.93	1.44
25	2.03	2.10	2.07	1.90	2.00	2.01	1.98	1.93	1.78	1.64	1.46
24	1.84	1.86	1.89	1.98	1.84	1.84	1.92	1.89	1.68	1.64	1.33
23	1.80	1.81	1.89	1.80	1.76	1.84	1.86	1.77	1.67	1.50	1.36
22	1.84	1.86	1.74	1.74	1.68	1.63	1.56	1.46	1.36	1.36	0.86
Means=35.0	2.71	2.75	2.77	2.70	2.69	2.69	2.70	2.48	2.42	2.15	1.58

STATION 5.

56	5.13	4.95	5.04	5.03	4.98	4.69	4.56	4.41	3.99	3.65	3.04
40	2.38	2.55	2.72	2.66	2.75	2.78	2.75	2.52	2.38	2.22	1.68
36	2.86	2.67	2.61	2.65	2.65	2.86	2.88	2.76	2.66	2.17	1.78
25	2.37	2.18	2.03	2.16	2.12	2.14	2.19	2.06	1.81	1.50	1.20
31	3.04	2.98	3.07	3.07	3.07	3.13	2.98	2.91	2.63	2.34	1.93
28	2.75	2.73	2.73	2.79	2.84	2.85	2.71	2.65	2.46	2.40	1.87
25	2.15	2.05	2.06	2.08	2.18	2.03	2.04	2.11	1.82	1.74	1.49
26	2.50	2.48	2.34	2.44	2.44	2.34	2.37	2.26	2.12	2.00	1.46
27	2.60	2.43	2.50	2.57	2.34	2.35	2.30	2.24	2.23	1.90	1.58
24	2.19	2.14	1.93	1.87	2.03	1.86	1.84	1.85	1.90	1.72	1.39
23	1.87	1.84	1.87	1.87	1.83	1.84	1.75	1.74	1.64	1.45	1.42
20	1.68	1.68	1.69	1.68	1.67	1.64	1.56	1.48	1.41	1.30	0.63
Means=30.1	2.63	2.56	2.55	2.57	2.58	2.54	2.49	2.42	2.26	2.03	1.62

STATION 6.

66	4.88	5.95	5.55	5.70	5.45	5.78	5.13	5.13	4.56	4.26	3.41
40	2.16	2.24	2.41	2.41	2.52	2.69	2.94	2.80	2.66	2.38	1.96
34	2.69	2.65	2.64	2.66	2.78	2.86	2.86	2.61	2.47	2.05	1.90
24	1.84	2.12	2.20	2.06	1.97	2.10	1.96	1.79	1.68	1.54	1.43
28	3.07	3.01	3.02	3.01	3.04	2.87	2.72	2.60	2.60	2.34	2.03
26	2.82	2.80	2.79	2.68	2.72	2.62	2.53	2.42	2.34	2.26	1.96
23	2.12	2.07	2.00	1.98	1.91	2.00	1.92	1.88	1.78	1.59	1.58
23	2.28	2.26	2.17	2.27	2.24	1.96	1.93	1.92	1.86	1.70	1.55
24	2.50	2.47	2.44	2.32	2.28	2.33	2.13	2.07	2.00	2.06	1.58
21	1.93	1.96	1.87	1.87	1.77	1.77	1.68	1.68	1.58	1.58	1.30
20	1.62	1.62	1.62	1.55	1.58	1.52	1.46	1.49	1.33	1.33	1.20
20	1.52	1.49	1.49	1.39	1.37	1.41	1.37	1.41	1.26	1.15	1.06
20	1.71	1.65	1.62	1.62	1.55	1.55	1.50	1.31	1.31	1.38	1.17
Means=28.4	2.41	2.48	2.45	2.42	2.40	2.42	2.32	2.24	2.11	1.97	1.70

Velocities in f et per second at each tenth of depth, &c.—Continued.

STATION 7.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
63	5.18	5.51	5.70	5.76	5.17	5.97	5.94	5.73	4.53	3.87	3.20
52	5.35	5.00	5.02	5.00	4.63	4.69	4.86	4.00	4.23	3.89	2.48
39	2.58	2.55	2.61	2.58	2.62	2.80	2.78	2.75	2.74	2.28	2.13
27	2.53	2.72	2.82	2.81	2.92	2.88	2.79	2.62	2.52	2.40	1.96
17	2.00	2.00	1.92	1.98	1.94	1.96	1.88	1.78	1.71	1.59	1.55
20	2.79	2.72	2.69	2.63	2.57	2.47	2.47	2.44	2.31	2.25	1.90
17	2.25	2.22	2.08	2.10	2.05	2.05	1.95	1.92	1.83	1.67	1.49
14	1.87	1.88	1.88	1.90	1.80	1.68	1.73	1.74	1.66	1.48	1.49
15	2.09	2.08	2.06	1.94	1.94	1.90	1.89	1.88	1.85	1.67	1.36
16	2.25	2.25	2.15	2.10	2.19	2.03	2.00	1.90	2.00	1.71	1.65
14	1.80	1.83	1.86	1.75	1.71	1.73	1.75	1.60	1.46	1.36	1.27
14	1.46	1.44	1.37	1.33	1.33	1.35	1.31	1.23	1.18	1.01	1.17
11	1.14	1.14	1.14	1.11	1.08	1.11	0.98	0.98	1.01	0.95	0.89
14	1.37	1.37	1.31	1.35	1.37	1.33	1.31	1.27	1.24	1.18	1.11
ns=23.8	2.48	2.48	2.47	2.45	2.38	2.42	2.40	2.27	2.16	1.95	1.69

STATION 8.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
23	3.05	3.05	3.00	2.95	2.85	2.80	2.62	2.72	2.49	2.26	2.10
31	2.69	2.72	2.72	2.78	2.83	2.97	3.08	2.89	2.72	2.58	2.38
21	2.88	2.91	2.91	2.85	2.75	2.60	2.53	2.44	2.47	2.15	1.87
10	1.96	1.96	1.89	1.87	1.92	1.90	1.89	1.97	1.97	1.83	1.74
15	2.72	2.69	2.60	2.46	2.35	2.49	2.52	2.31	2.43	2.26	1.87
10	2.12	2.12	2.10	2.06	2.05	2.06	2.09	2.00	1.88	1.85	1.68
9	2.19	2.08	2.03	2.04	2.03	1.96	1.93	1.92	1.70	1.58	1.58
10	2.19	2.19	2.13	2.09	1.96	2.12	2.00	2.07	1.89	1.95	1.58
10	2.25	2.25	2.22	2.25	2.09	2.22	2.22	2.06	1.87	1.93	1.90
8	1.93	1.93	1.95	1.94	1.95	1.86	1.92	1.79	1.78	1.70	1.55
7	1.39	1.39	1.38	1.36	1.36	1.34	1.34	1.30	1.23	1.37	1.11
6	1.14	1.14	1.14	1.14	1.14	1.04	1.01	1.01	0.89	0.86	0.86
8	1.42	1.43	1.42	1.34	1.37	1.36	1.26	1.23	1.15	1.13	1.01
ns=13.0	2.15	2.14	2.11	2.09	2.05	2.06	2.03	1.98	1.88	1.80	1.63

STATION 9.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
62	5.29	5.41	5.02	5.09	5.00	4.74	5.04	4.60	4.10	4.12	2.76
37	4.70	4.71	4.59	4.56	4.47	4.42	4.02	3.63	3.57	3.30	2.50
25	2.89	2.80	2.83	2.63	2.60	2.63	2.57	2.25	2.22	1.96	1.76
27	3.40	3.38	3.40	3.10	2.96	2.83	2.69	2.49	2.34	2.30	2.06
21	2.98	2.88	2.85	2.85	2.60	2.63	2.44	2.41	2.12	2.19	2.03
10	2.03	2.03	2.03	2.03	2.00	2.03	1.93	1.93	1.68	1.81	1.61
14	2.75	2.68	2.69	2.58	2.58	2.53	2.36	2.20	2.25	2.23	2.09
10	2.15	2.15	2.12	2.07	2.18	2.06	2.13	1.90	1.91	1.77	1.90
9	2.09	2.09	2.06	2.06	2.01	1.93	1.81	1.92	1.75	1.72	1.30
9	2.15	2.15	2.11	2.13	2.18	2.12	2.08	2.09	1.97	1.92	1.77
10	2.34	2.34	2.24	2.24	2.14	2.06	2.02	1.95	1.94	1.92	1.61
8	2.00	2.00	2.01	1.94	1.90	1.86	1.80	1.73	1.70	1.54	1.49
6	1.49	1.49	1.48	1.42	1.42	1.42	1.41	1.35	1.33	1.26	1.11
5	1.33	1.33	1.33	1.32	1.29	1.27	1.19	1.15	1.15	1.14	1.01
7	1.49	1.49	1.52	1.46	1.39	1.33	1.36	1.36	1.36	1.20	1.17
ns=17.3	2.60	2.60	2.55	2.50	2.45	2.39	2.32	2.20	2.09	2.02	1.74

STATION 10.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
27	3.62	3.38	3.25	3.13	2.98	2.83	2.60	2.64	2.35	2.12	1.91
22	3.01	2.95	2.84	2.74	2.66	2.53	2.55	2.32	2.32	2.12	1.84
12	2.03	2.03	2.01	1.98	2.03	1.96	1.98	1.90	1.78	1.77	1.65
11	2.15	2.16	2.14	2.14	2.10	2.16	2.07	1.95	1.86	1.78	1.58
10	2.12	2.12	2.12	2.02	1.88	2.00	1.93	1.99	1.90	1.73	1.81
10	2.19	2.19	2.21	2.17	2.02	2.06	2.03	1.87	1.91	1.75	1.68
11	2.34	2.34	2.28	2.06	2.15	2.19	2.15	2.09	1.90	1.81	1.74
9	2.03	2.03	2.08	2.09	2.00	2.00	1.90	1.85	1.84	1.76	1.68
7	1.52	1.52	1.53	1.57	1.55	1.55	1.51	1.45	1.38	1.29	1.14
6	1.30	1.30	1.30	1.27	1.23	1.17	1.22	1.18	1.12	1.07	1.04
7	1.68	1.66	1.64	1.59	1.48	1.52	1.45	1.45	1.38	1.31	1.11
ns=12.0	2.18	2.15	2.13	2.07	2.01	2.00	1.94	1.88	1.79	1.68	1.56

Velocities in feet per secoud at each tenth of depth, &c.—Continued.

STATION 11.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
28	3.52	3.37	3.26	3.18	3.03	2.91	2.75	2.55	2.36	2.16	1.81
20	2.69	2.69	2.64	2.64	2.57	2.48	2.39	2.22	2.22	2.20	1.81
12	2.09	2.09	2.08	2.03	2.03	2.03	1.97	1.89	1.85	1.78	1.68
16	2.66	2.72	2.75	2.68	2.85	2.68	2.69	2.52	2.41	2.38	2.19
12	2.41	2.40	2.30	2.33	2.29	2.15	2.18	2.20	1.94	2.06	1.71
11	2.34	2.34	2.31	2.31	2.15	2.25	2.19	2.15	1.96	1.93	1.87
11	2.15	2.15	2.12	2.09	2.25	2.12	2.09	1.93	1.84	1.96	1.81
12	2.41	2.40	2.33	2.31	2.28	2.20	2.23	2.04	1.91	1.90	1.74
10	2.19	2.19	2.11	2.09	2.00	2.06	2.03	1.90	1.93	1.89	1.58
8	1.71	1.71	1.69	1.58	1.62	1.57	1.57	1.59	1.49	1.45	1.27
7	1.39	1.39	1.40	1.33	1.34	1.34	1.25	1.18	1.19	1.17	1.01
8	1.74	1.75	1.75	1.59	1.69	1.65	1.69	1.60	1.43	1.38	1.33
Means=13.0	2.28	2.27	2.23	2.18	2.17	2.12	2.09	1.98	1.88	1.85	1.65

STATION 12.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
41	4.65	4.50	4.50	4.48	4.27	3.84	3.91	3.79	3.58	3.16	2.28
28	2.78	2.73	2.71	2.51	2.61	2.46	2.33	2.16	2.06	1.90	1.68
29	3.30	3.24	3.07	2.89	2.73	2.61	2.48	2.39	2.23	2.03	1.69
17	3.17	3.13	3.06	3.07	2.98	2.91	2.89	2.72	2.62	2.53	2.19
13	2.37	2.37	2.41	2.38	2.30	2.28	2.23	2.16	2.00	2.05	1.90
12	2.50	2.50	2.44	2.47	2.34	2.12	2.03	2.15	2.00	2.09	1.77
12	2.21	2.32	2.37	2.28	2.21	2.15	2.20	2.15	2.06	1.92	1.87
14	2.60	2.61	2.50	2.46	2.51	2.42	2.33	2.34	2.13	2.02	1.90
11	2.22	2.22	2.22	2.28	2.25	2.22	2.12	1.96	2.03	1.84	1.77
9	1.71	1.71	1.79	1.75	1.72	1.58	1.64	1.64	1.58	1.37	1.49
8	1.55	1.51	1.54	1.41	1.36	1.36	1.42	1.36	1.37	1.22	1.20
9	1.90	1.90	1.87	1.78	1.68	1.62	1.68	1.58	1.62	1.52	1.49
Means=17.0	2.59	2.56	2.54	2.48	2.40	2.30	2.26	2.20	2.11	1.97	1.76

STATION 13.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
32	3.47	3.40	3.48	3.42	3.19	3.27	3.14	2.99	2.70	2.67	2.43
31	3.24	3.18	2.99	2.83	2.70	2.51	2.41	2.19	2.06	1.81	1.87
21	2.79	2.75	2.75	2.69	2.66	2.57	2.50	2.37	2.15	2.12	1.74
14	2.28	2.25	2.19	2.15	2.13	2.06	2.07	2.06	2.00	1.96	1.71
14	2.69	2.67	2.70	2.63	2.55	2.60	2.57	2.45	2.26	2.15	2.09
13	2.37	2.38	2.36	2.35	2.32	2.22	2.20	2.15	2.00	1.82	1.20
14	2.75	2.72	2.56	2.59	2.59	2.47	2.46	2.36	2.21	2.08	1.68
11	2.31	2.31	2.34	2.34	2.28	2.25	2.31	2.09	2.12	1.93	1.80
9	1.90	1.90	1.84	1.87	1.78	1.72	1.71	1.62	1.58	1.46	1.49
9	1.55	1.52	1.49	1.49	1.42	1.50	1.39	1.28	1.17	1.24	1.30
10	1.93	1.93	1.93	1.87	1.83	1.90	1.79	1.78	1.74	1.56	1.74
Means=16.2	2.48	2.46	2.42	2.38	2.31	2.28	2.23	2.12	2.00	1.89	1.6[illegible]

STATION 14.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
42	4.19	4.18	4.15	3.87	3.96	3.85	3.40	3.64	3.30	2.81	[illegible]
31	3.24	3.14	2.99	2.73	2.70	2.57	2.32	2.32	2.09	1.81	[illegible]
21	2.91	2.95	2.82	2.79	2.66	2.57	2.47	2.34	2.15	1.90	[illegible]
14	2.34	2.35	2.32	2.25	2.16	2.15	2.13	2.09	1.94	1.81	[illegible]
14	2.31	2.31	2.27	2.25	2.22	2.12	2.05	2.02	1.92	1.76	[illegible]
13	2.85	2.83	2.73	2.64	2.60	2.58	2.49	2.47	2.35	2.17	[illegible]
12	2.41	2.39	2.27	2.33	2.32	2.31	2.32	2.16	2.02	1.86	[illegible]
13	2.66	2.67	2.60	2.53	2.54	2.44	2.35	2.36	2.39	2.22	[illegible]
14	2.63	2.60	2.49	2.52	2.54	2.52	2.44	2.29	2.07	1.94	[illegible]
11	2.50	2.50	2.44	2.31	2.22	2.19	2.19	1.96	1.93	1.77	[illegible]
10	2.03	2.03	2.00	1.99	1.93	2.00	1.87	1.85	1.88	1.78	[illegible]
8	1.55	1.56	1.61	1.53	1.50	1.42	1.47	1.41	1.45	1.84	[illegible]
Means=17.0	2.64	2.63	2.56	2.48	2.45	2.39	2.29	2.26	2.12	1.89	[illegible]

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 15.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
57	4.99	4.93	4.50	4.86	5.10	4.57	4.65	4.42	3.79	3.63	2.86
33	2.96	2.86	2.76	2.77	2.72	2.61	2.43	2.19	2.02	1.80	1.30
22	2.53	2.61	2.49	2.43	2.33	2.25	2.14	1.85	1.85	1.59	1.11
16	2.19	2.16	2.09	2.04	1.96	2.01	1.93	1.88	1.81	1.70	1.58
15	2.60	2.64	2.57	2.50	2.44	2.42	2.41	2.20	2.12	1.94	1.84
14	2.37	2.36	2.28	2.28	2.21	2.26	2.23	2.20	1.19	2.04	1.87
15	2.66	2.64	2.54	2.49	2.41	2.44	2.44	2.42	2.25	2.22	1.61
16	2.66	2.63	2.63	2.64	2.63	2.55	2.53	2.42	2.41	2.05	2.06
15	2.63	2.62	2.60	2.51	2.36	2.34	2.35	2.33	2.22	2.05	1.81
12	2.41	2.40	2.32	2.24	2.24	2.16	2.08	2.02	1.94	1.93	1.74
11	1.87	1.87	1.93	1.87	1.87	1.93	1.77	1.74	1.74	1.49	1.30
10	1.58	1.58	1.61	1.61	1.57	1.39	1.46	1.47	1.47	1.34	1.27
11	2.06	2.06	2.04	2.09	2.07	2.03	1.93	1.75	1.77	1.79	1.62
ans=19.0	2.58	2.57	2.49	2.49	2.45	2.38	2.33	2.22	2.12	1.97	1.60

STATION 16.

35	3.18	3.03	2.88	2.62	2.55	2.38	2.22	2.02	1.94	1.58	1.08
25	2.31	2.30	2.29	2.21	2.13	2.03	1.92	1.84	1.71	1.42	1.17
19	1.96	1.90	1.89	1.83	1.78	1.77	1.69	1.65	1.54	1.47	1.24
21	2.72	2.75	2.69	2.60	2.60	2.57	2.37	2.31	2.15	2.03	1.71
18	1.96	1.99	1.94	1.96	1.97	1.90	1.70	1.74	1.58	1.40	1.24
18	2.22	2.20	2.20	2.21	2.08	2.14	1.99	1.90	1.79	1.60	1.52
18	2.44	2.37	2.33	2.34	2.24	2.20	2.08	2.06	1.92	1.82	1.43
18	2.25	2.25	2.13	2.18	2.10	2.02	1.97	1.84	1.73	1.67	1.36
15	2.12	2.11	2.04	2.03	1.90	1.93	1.91	1.80	1.73	1.58	1.42
13	1.77	1.77	1.74	1.72	1.68	1.68	1.65	1.54	1.44	1.35	1.20
12	1.49	1.48	1.38	1.37	1.38	1.32	1.31	1.27	1.18	1.12	1.01
12	1.80	1.86	1.73	1.81	1.71	1.90	1.82	1.62	1.46	1.65	1.42
ans=18.7	2.18	2.17	2.10	2.07	2.01	1.99	1.89	1.80	1.68	1.56	1.32

STATION 17.

53	3.59	3.40	3.84	3.90	3.40	3.28	3.10	3.01	2.44	1.80	1.21
33	2.57	2.53	2.26	2.08	1.92	1.75	1.60	1.40	1.39	1.27	1.05
24	1.99	1.83	1.86	1.72	1.75	1.66	1.52	1.40	1.34	1.25	0.89
20	1.68	1.68	1.53	1.41	1.45	1.38	1.26	1.23	1.41	1.33	1.14
23	2.47	2.42	2.28	2.27	2.12	2.14	2.02	1.96	2.09	1.98	1.46
15	1.17	1.22	1.30	1.28	1.32	1.27	1.24	1.32	1.24	1.09	0.86
19	1.93	1.88	1.90	2.00	1.85	1.96	1.94	1.79	1.71	1.62	1.55
16	1.81	1.87	1.86	1.93	1.89	1.77	1.75	1.65	1.50	1.29	0.89
15	1.74	1.69	1.58	1.70	1.60	1.56	1.37	1.31	1.19	1.24	1.01
14	1.42	1.45	1.53	1.43	1.37	1.25	1.19	1.12	1.08	1.06	0.79
12	0.95	0.96	1.05	1.09	1.10	1.14	1.02	0.90	0.77	0.84	0.76
14	1.71	1.69	1.57	1.66	1.60	1.52	1.45	1.41	1.40	1.22	1.24
ans=21.5	1.92	1.88	1.88	1.87	1.78	1.72	1.62	1.54	1.46	1.33	1.07

MEAN VALUES OF STATION MEANS.

tation No.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
1	1.43	1.43	1.46	1.46	1.43	1.42	1.38	1.37	1.32	1.24	1.06
2	1.91	1.94	1.99	2.02	1.99	1.96	1.89	1.81	1.69	1.54	1.26
3	2.38	2.41	2.42	2.44	2.40	2.35	2.29	2.18	2.04	1.88	1.51
4	2.71	2.75	2.77	2.70	2.69	2.69	2.70	2.48	2.42	2.15	1.58
5	2.63	2.56	2.55	2.57	2.58	2.54	2.49	2.42	2.26	2.03	1.62
6	2.41	2.48	2.45	2.42	2.40	2.42	2.32	2.24	2.11	1.97	1.70
7	2.48	2.48	2.47	2.45	2.38	2.42	2.40	2.27	2.16	1.95	1.69
8	2.15	2.14	2.11	2.09	2.05	2.06	2.03	1.98	1.88	1.80	1.63
9	2.60	2.60	2.[illegible]5	2.50	2.45	2.39	2.32	2.20	2.09	2.02	1.74
10	2.18	2.15	2.13	2.07	2.01	2.00	1.94	1.88	1.79	1.68	1.56
11	2.28	2.27	2.23	2.18	2.17	2.12	2.09	1.98	1.88	1.85	1.65
12	2.59	2.56	2.54	2.48	2.40	2.30	2.26	2.20	2.11	1.97	1.76
13	2.48	2.46	2.42	2.38	2.31	2.28	2.23	2.12	2.00	1.89	1.69
14	2.64	2.63	2.56	2.48	2.45	2.39	2.29	2.26	2.12	1.89	1.66
15	2.58	2.57	2.49	2.49	2.45	2.38	2.33	2.22	2.12	1.97	1.69
16	2.18	2.17	2.10	2.07	2.01	1.99	1.89	1.80	1.68	1.56	1.32
17	1.92	1.88	1.88	1.87	1.78	1.72	1.62	1.54	1.46	1.33	1.07
Ieans=	2.33	2.32	2.30	2.27	2.23	2.20	2.15	2.06	1.95	1.81	1.54

Velocities in feet per second at each tenth of depth, &c.—**Continued.**

MEAN VALUES OF ALL OBSERVATIONS.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
	2.34	2.34	2.32	2.29	2.25	2.22	2.17	2.07	1.97	1.84	1.85

2.—COLUMBUS, KENTUCKY.

Ratings of meters used at Columbus, Ky.

Locality.	Date.	Meter.	Number of observations.	Registrations per revolution.	*a*.	*b*.	Range of velocities per second.	Where taken.
	1881.						*Feet.*	
Saint Louis	Nov. 14	3	23	1	0.0639	0.2578	2.140— 8.520	Reservoir, Saint Louis.
	1882.							
Columbus, Ky	Mar. 17	23	15	1	0.0604	0.333	1.960 - 6.897	In backwater.
Do	Apr 3	23	14	1	0.0647	0.416	3.333— 9.091	Do.
Do	Apr 20	3	14	1	0.0574	0.795	3.207—11.111	In a lake.
Do	May 17	8	17	1	0.0634	0.425	1.734—10.000	In a small pond.
Do*	May 23	23	13	1	0.0675	0.4074	2.973—10.345	In a lake.
Do*	June 10	23	18	1	0.0694	0.2591	2.586—10.310	Do.
Do	July 11	23	21	1	0.0634	0.2843	1.154—10.000	Do.
Do	July 19	6	38	1	0.0605	0.2073	0.739—10.345	Do.
Do	Aug. 9	23	24	1	0.0596	0.2680	0.826— 8.000	Do.
Do	Aug 23	23	20	1	0.0501	0.2798	1.176— 8.000	Do.
Do†	Sept. 6	23	14	1	0.0605	0.3323	1.031— 6.667	Do.
Do‡	Sept. 6	6	13	1	0.0572	0.2611	1.333— 6.452	Do.
Do	Sept. 10	6	20	1	0.0507	0.2148	0.699— 8.696	Do.
Do	Sept. 19	23	21	1	0.0610	0.2884	0.877— 8.333	Do.
Do	Oct. 14	6	15	1	0.0593	0.3004	0.990— 8.333	Do.
Do	Oct. 30	6	10	1	0.0501	0.4137	1.000— 8.696	Do.
Do	Nov. 20	6	10	1	0.0646	0.3010	1.149— 8.000	Do.

* With block. † Meter in bad condition. ‡ Meter in good condition.

Velocities in feet per second at each tenth of depth as resulting from the velocity observations made at Columbus, Ky., in 1882.

STATION 1.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
63.0	0.868	1.103	1.506	1.589	1.610	1.631	1.620	1.558	1.374	1.065	0.666

STATION 2.

62.0	3.329	3.508	3.422	3.306	3.090	3.370	3.720	3.320	3.066	2.800	2.878
52.0	2.350	2.453	2.470	2.565	2.675	2.790	2.640	2.150	1.625	1.725	1.[illegible]
47.6	2.182	2.600	2.030	2.680	2.090	2.585	2.405	2.410	2.184	[illegible]	1.585
36.9	1.300	1.515	1.585	1.550	1.575	1.003	1.590	1.470	1.320	1.100	0.737
34.0	0.895	1.200	1.350	1.430	1.489	1.607	1.540	1.426	1.300	1.150	0.965
Means=46.6	2.023	2.235	2.293	2.306	2.420	2.403	2.398	2.155	1.939	1.741	1.441

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 3.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
72.0	4.231	4.977	5.020	5.225	5.160	5.268	4.870	4.575	4.752	4.050	3.843
60.5	4.472	4.978	4.820	4.785	4.860	4.914	4.780	4.663	4.475	3.745	3.329
68.0	4.663	5.060	5.010	5.020	5.065	4.979	4.872	4.575	4.775	4.180	3.329
70.0	3.771	4.630	4.979	5.040	4.914	4.914	4.971	4.853	4.390	4.080	3.519
66.5	3.836	4.490	4.663	4.626	4.598	4.480	4.310	4.200	4.025	4.090	3.138
62.0	3.301	4.030	4.210	4.126	4.075	3.953	3.718	3.640	3.240	2.450	2.225
62.0	3.329	4.120	4.380	4.570	4.720	4.630	4.535	4.520	4.250	3.700	3.645
66.0	4.090	4.300	4.185	4.630	4.970	4.700	4.471	4.290	4.325	3.500	2.884
59.0	2.823	3.394	3.535	3.727	3.760	3.709	3.825	3.820	3.520	3.070	2.313
62.0	3.454	3.660	4.216	4.425	4.370	4.475	4.400	4.030	3.730	3.175	2.823
51.5	2.512	2.630	2.740	2.845	2.950	2.975	2.830	2.662	2.660	2.835	1.643
42.0	1.759	1.840	1.910	1.936	1.936	1.975	1.940	1.840	1.609	1.365	1.049
36.0	0.770	1.090	1.310	1.320	1.425	1.368	1.380	1.420	1.325	1.150	1.012
34.0	1.416	1.550	1.550	1.575	1.550	1.440	1.450	1.390	1.285	1.175	1.122
ns=58.6	3.173	3.696	3.751	3.846	3.882	3.841	3.739	3.606	3.461	3.005	2.562

STATION 4.

73.0	4.491	4.960	5.240	5.225	5.173	5.150	4.860	4.410	4.680	3.780	3.715
74.0	4.297	4.960	5.310	5.140	5.225	5.074	4.990	4.750	4.760	4.345	3.393
65.0	3.740	4.370	4.538	4.575	4.640	4.440	4.475	4.330	4.040	3.300	3.112
66.0	3.594	4.484	4.410	4.335	4.475	4.419	4.280	4.140	4.025	3.800	2.962
69.0	3.658	4.510	4.575	4.740	4.690	4.730	4.500	3.900	3.733	3.467	3.404
66.5	3.849	4.630	4.575	4.770	4.865	4.950	4.860	4.470	3.860	3.460	2.453
73.0	4.355	5.330	5.790	5.825	5.820	5.500	5.590	5.390	4.960	4.600	4.294
68.0	3.901	4.789	5.010	5.227	5.090	4.853	4.730	4.325	4.216	4.025	3.455
65.0	3.301	4.130	4.430	4.600	4.631	4.506	4.320	4.000	3.873	3.150	2.540
68.0	3.555	4.920	4.777	4.757	4.930	4.930	4.880	4.740	4.150	3.770	3.491
70.0	4.535	4.977	5.020	5.000	5.410	5.325	5.357	5.045	4.725	4.550	3.900
63.0	3.454	3.970	4.375	4.330	4.330	4.380	4.150	3.860	3.770	2.375	2.313
57.0	1.884	2.570	2.700	2.820	2.880	2.775	2.675	2.580	2.525	2.000	1.227
53.0	2.114	2.465	2.575	2.630	2.646	2.610	2.475	2.320	2.085	1.830	1.638
45.0	1.980	2.220	2.270	2.055	2.120	2.240	2.172	2.025	1.825	1.430	1.142
ns=65.0	3.514	4.219	4.373	4.402	4.462	4.392	4.288	4.019	3.815	3.325	2.869

STATION 5.

75.0	4.229	4.660	4.895	4.864	5.100	5.000	4.868	4.674	4.660	4.075	3.728
75.0	5.742	6.490	6.225	6.123	5.655	5.780	5.660	4.789	4.155	5.290	4.407
69.0	4.661	4.880	5.125	5.075	5.250	4.880	5.125	4.920	4.520	4.470	4.090
69.0	4.025	4.520	4.725	5.010	4.920	4.770	4.630	4.345	4.190	4.120	3.394
63.0	3.084	2.925	3.075	3.215	3.225	3.000	2.550	2.530	1.890	*1.600	*1.400
50.0	1.936	2.180	2.180	2.250	2.325	2.290	2.180	2.040	1.880	1.640	1.344
55.0	1.647	2.350	2.350	2.210	2.275	2.245	2.245	2.225	2.020	1.875	1.350
49.0	1.607	1.725	1.840	1.670	1.765	1.724	1.715	1.590	1.489	1.300	1.073
47.0	1.948	2.070	2.278	2.230	2.090	2.125	2.140	2.068	1.825	1.425	1.005
ns=61.3	3.209	3.533	3.633	3.627	3.623	3.535	3.457	3.242	2.959	2.866	2.421

* Interpolated.

STATION 6.

65.0	2.720	3.380	3.325	3.355	3.324	3.250	2.970	2.980	2.740	2.375	2.052
60.0	1.876	2.375	2.408	2.525	2.470	2.585	2.560	2.260	1.995	1.725	1.585
62.5	2.037	2.360	2.550	2.425	2.380	2.270	2.380	2.170	2.175	1.875	1.693
64.0	2.066	2.600	2.565	2.660	2.685	2.640	2.520	2.535	2.290	1.995	1.708
51.5	1.845	1.820	1.845	1.670	1.740	1.728	1.650	1.607	1.450	1.220	1.073
ns=60.6	2.109	2.507	2.539	2.527	2.520	2.495	2.416	2.310	2.130	1.838	1.622

STATION 7.

66.0	3.084	3.320	3.580	3.560	3.567	3.530	3.425	3.150	3.300	2.770	2.176
64.0	2.231	2.702	2.702	2.725	2.785	2.823	2.725	2.550	2.680	2.025	1.585
63.0	1.887	2.275	2.600	2.450	2.660	2.542	2.525	2.350	2.275	2.030	1.708
57.0	1.887	1.980	1.950	1.995	2.005	1.950	1.830	1.770	1.720	1.540	1.049
53.0	1.489	1.600	1.783	1.760	1.785	1.718	1.667	1.667	1.570	1.100	0.895
58.0	1.714	1.950	2.008	2.008	2.090	2.110	2.060	1.955	1.868	1.627	1.188
ns=60.2	2.049	2.304	2.437	2.416	2.482	2.446	2.372	2.240	2.236	1.849	1.438

Velocities in feet per second at each tenth of depth, &c.—**Continued.**

STATION 8.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
71.0	2.960	3.490	3.624	3.780	3.650	3.749	3.755	3.580	3.400	2.760	2.415
66.0	3.201	3.430	3.300	3.310	3.250	3.185	3.201	3.200	2.768	2.285	2.124
65.0	2.208	2.650	2.755	2.785	2.700	2.665	2.665	2.570	2.430	2.505	2.037
62.0	2.066	2.230	2.450	2.400	2.253	2.302	2.230	2.123	2.040	1.826	1.586
59.5	1.647	2.050	2.184	2.184	2.130	2.040	2.123	2.005	1.960	1.838	1.529
58.0	1.570	1.860	1.970	1.960	2.057	2.080	2.057	1.930	1.975	1.520	1.204
57.0	1.724	1.875	1.945	1.950	1.985	2.023	1.965	1.925	1.724	1.515	1.429
Means=62.6	2.197	2.512	2.604	2.624	2.575	2.578	2.571	2.476	2.328	2.036	1.761

STATION 9.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
70.0	3.324	3.825	4.150	4.270	4.220	4.130	4.150	3.725	3.475	3.230	2.597
66.0	3.021	3.695	3.225	3.365	3.360	3.319	3.260	3.230	3.020	2.800	2.304
58.0	1.691	1.880	2.050	2.181	2.280	2.325	2.230	2.075	1.936	1.750	1.508
56.0	1.771	2.035	2.210	2.300	2.302	2.250	2.265	2.335	2.360	1.960	1.477
Means=62.5	2.452	2.709	2.909	3.029	3.041	3.006	2.976	2.841	2.698	2.435	1.972

STATION 10.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
62.0	2.662	3.218	3.290	3.275	3.345	3.475	3.420	3.260	2.875	2.640	2.361
57.0	1.887	2.500	2.450	2.364	2.480	2.460	2.510	2.542	2.400	2.230	2.066
62.0	2.123	2.960	3.120	3.040	3.140	3.080	2.820	2.860	2.690	2.380	2.005
58.0	1.887	2.115	2.220	2.245	2.295	2.245	2.006	2.080	1.940	1.710	1.350
57.0	2.057	2.175	2.320	2.310	2.364	2.220	2.302	2.075	1.960	1.691	1.449
56.0	1.771	2.060	2.240	2.230	2.184	2.255	2.260	2.110	2.000	1.700	1.416
57.0	1.654	1.870	1.835	1.946	2.068	2.068	2.608	1.885	1.695	1.350	0.885
Means=58.4	2.006	2.405	2.496	2.487	2.554	2.543	2.475	2.402	2.223	1.957	1.647

STATION 11.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
66.0	4.050	4.870	4.825	4.657	4.720	4.805	4.450	4.294	4.350	3.880	2.902
72.0	4.294	4.800	4.719	4.980	4.680	4.730	4.330	4.500	4.370	3.525	2.720
61.0	2.540	3.021	3.319	3.350	3.440	3.330	3.250	3.120	3.140	2.740	2.512
56.5	2.148	2.480	2.450	2.449	2.630	2.440	2.340	2.425	2.220	2.240	2.148
56.0	1.765	2.302	2.290	2.481	2.542	2.495	2.520	2.330	2.861	2.120	1.617
55.0	1.887	2.318	2.370	2.424	2.603	2.525	2.424	2.630	2.455	2.210	1.887
51.0	1.714	2.100	2.184	2.225	2.184	2.225	2.184	2.184	2.050	1.825	1.891
Means=59.6	2.628	3.127	3.165	3.224	3.256	3.221	3.071	3.069	2.902	2.649	2.244

STATION 12.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
69.0	3.964	4.518	4.520	4.700	4.630	4.935	4.690	4.475	3.950	3.750	3.635
67.0	4.174	4.450	4.537	4.537	4.525	4.550	4.070	3.875	3.350	2.830	3.022
60.0	3.021	3.079	3.079	3.079	3.118	3.170	3.201	3.030	2.770	2.775	2.512
60.5	2.720	2.870	3.070	3.140	3.140	3.140	3.140	2.980	2.920	2.690	1.704
55.0	2.066	2.450	2.590	2.585	2.630	2.660	2.620	2.665	2.650	2.380	2.005
52.0	1.691	2.040	2.119	2.280	2.225	2.270	2.180	2.057	1.815	1.810	1.632
51.0	1.508	2.020	2.119	2.080	2.119	2.119	1.998	1.925	1.920	1.920	1.753
50.0	1.714	2.075	2.184	2.000	2.035	2.335	2.410	2.260	2.100	1.840	1.714
38.0	1.771	1.940	2.070	2.110	2.080	2.180	2.068	2.005	1.891	1.750	1.416
Means=55.8	2.514	2.827	2.921	2.956	2.945	3.029	2.931	2.808	2.596	2.416	2.177

STATION 13.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
64.0	3.901	4.217	4.180	3.950	3.620	3.655	3.650	3.645	3.820	3.450	2.437
69.0	3.835	4.150	4.150	3.925	3.925	4.070	3.850	3.680	3.180	2.890	3.013
66.0	2.779	3.480	3.420	3.530	3.625	3.560	3.355	3.360	3.430	3.350	2.295
65.0	2.720	3.000	2.810	2.810	2.750	2.781	2.650	2.601	2.170	2.063	1.884
55.0	1.541	1.930	2.025	1.920	1.904	2.020	1.920	1.805	1.675	1.720	1.541
60.0	2.066	2.520	2.630	2.420	2.425	2.280	2.385	2.302	2.125	1.990	1.826
54.0	1.753	1.675	1.830	2.035	2.057	2.057	2.057	1.878	1.691	1.645	1.325
53.0	1.537	1.925	2.010	2.030	2.063	2.035	2.008	2.190	1.930	1.778	1.594
Means=60.8	2.517	[illegible]	2.882	[illegible]	[illegible]	2.807	2.734	2.683	2.503	2.361	1.980

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 14.

Depth.	Surface.	.1	2	.3	.4	.5	.6	.7	.8	.9	Bottom.
63.0	3.009	3.880	4.090	4.190	4.030	4.045	4.145	4.217	4.118	3.900	2.437
59.0	3.645	3.964	3.775	3.870	4.025	4.060	3.815	3.600	3.175	3.100	2.503
41.0	1.190	1.550	1.785	1.770	1.690	1.720	1.670	1.543	1.520	1.518	1.429
38.0	1.062	1.413	1.416	1.380	1.325	1.380	1.450	1.438	1.416	1.250	0.885
Means=50.2	2.227	2.702	2.767	2.803	2.768	2.801	2.770	2.700	2.557	2.442	1.814

MEAN VALUES OF STATION MEANS.

No. of station.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
1	0.868	1.163	1.506	1.589	1.610	1.631	1.620	1.558	1.374	1.055	0.868
2	2.023	2.235	2.293	2.306	2.420	2.403	2.398	2.155	1.939	1.741	1.441
3	8.173	3.696	3.751	3.846	3.882	3.841	3.739	3.606	3.461	3.005	2.562
4	3.514	4.219	4.373	4.402	4.462	4.392	4.288	4.019	3.815	3.325	2.869
5	3.209	3.533	3.633	3.627	3.623	3.535	3.457	3.242	2.959	2.866	2.421
6	2.109	2.507	2.539	2.527	2.520	2.495	2.416	2.310	2.130	1.838	1.622
7	2.049	2.304	2.437	2.416	2.482	2.446	2.372	2.240	2.236	1.849	1.433
8	2.197	2.512	2.604	2.624	2.575	2.578	2.571	2.476	2.328	2.036	1.761
9	2.452	2.709	2.909	3.029	3.041	3.006	2.976	2.841	2.698	2.435	1.972
10	2.006	2.405	2.496	2.487	2.554	2.543	2.475	2.402	2.223	1.957	1.647
11	2.628	3.127	3.165	3.224	3.256	3.221	3.071	3.069	2.992	2.649	2.244
12	2.514	2.827	2.921	2.956	2.945	3.029	2.931	2.808	2.596	2.416	2.177
13	2.517	2.862	2.882	2.828	2.796	2.807	2.734	2.683	2.503	2.361	1.989
14	2.227	2.702	2.767	2.803	2.768	2.801	2.770	2.700	2.557	2.442	1.814
Means =	2.392	2.772	2.877	2.905	2.924	2.909	2.844	2.722	2.558	2.284	1.916

MEAN VALUES OF ALL OBSERVATIONS.

Means =	2.665	3.077	3.178	3.205	3.227	3.204	3.126	2.988	2.818	2.519	2.13c

Transverse velocities observed in bend above Columbus, Ky., at each twentieth of surface width 7 feet beneath surface.

	1882.								
	March 31.	April 28.	May 30.	June 30.	July 25.	September 11.	October 9.	November 15.	Means.
One-twentieth	....	3.742	4.890	4.340	3.180	1.750	....	1.600	3.250
Two-twentieths	5.920	4.220	5.290	4.610	3.370	2.160	1.450	1.745	3.596
Three-twentieths	6.080	4.280	5.420	4.850	3.625	2.217	1.620	1.984	3.760
Four-twentieths	6.191	4.560	5.550	5.240	3.680	2.180	1.753	2.140	3.912
Five-twentieths	6.260	4.680	5.690	5.220	3.825	2.425	1.920	2.340	4.015
Six-twentieths	6.280	4.750	5.775	5.300	4.225	2.550	2.175	2.650	4.213
Seven-twentieths	5.950	4.810	5.850	5.330	4.110	2.650	2.180	2.590	4.184
Eight-twentieths	5.384	4.730	5.680	5.178	4.217	2.690	2.440	2.720	4.130
Nine-twentieths	5.330	4.350	5.440	5.150	4.000	2.640	2.417	2.600	3.991
Ten-twentieths	5.350	4.230	5.280	5.080	3.816	2.680	2.260	2.700	3.925
Eleven-twentieths	5.425	4.285	5.000	4.760	3.890	2.532	1.938	2.440	3.784
Twelve-twentieths	5.550	4.375	5.230	4.700	3.760	2.370	1.730	2.400	3.764
Thirteen-twentieths	5.675	4.190	5.500	4.840	3.550	2.150	1.820	1.915	3.705
Fourteen-twentieths	5.750	4.420	4.850	4.820	3.500	2.250	1.835	2.245	3.709
Fifteen-twentieths	5.400	4.550	4.100	4.820	3.425	2.410	1.825	2.170	3.588
Sixteen-twentieths	4.675	4.650	3.160	3.470	3.700	2.050	1.600	1.938	3.155
Seventeen-twentieths	3.425	3.100	2.450	3.075	2.700	1.700	1.800	....	2.536
Eighteen-twentieths	....	....	....	2.452	1.750	....	....	....	2.101
Nineteen-twentieths	....	....	....	....	....	....	....	....	....

Areas in Beckwith's Bend.

[Datum areas computed with gauge readings at Columbus, Ky.]

Date.	Gauge.	Width.	Area.	+ Scour. — Fill.	Datum area.
	Feet	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Sq. feet.*
May 24	96.395	6,207.8	218,160	......	218,160
June 24	93.432	6,180.7	204,417	+ 4,602	222,771
July 17	88.236	6,145.8	160,572	−11,820	210,951
July 31	78.434	5,745.5	99,887	8,405	202,546
August 11	79.240	5,892.4	111,831	+13,254	215,800
August 22	75.837	5,625.1	88,109	— 4,035	211,765
September 12	73.835	5,645.9	74,061	+ 863	212,627
September 23	74.583	5,792.5	89,428	+ 7,329	219,956
October 5	69.926	5,025.9	54,861	— 3,967	215,989
October 25	68.021	3,606.0	53,773	+ 2,845	218,834
November 16	70.572	5,173.2	72,096	+ 7,048	225,882

3.—HELENA, ARKANSAS.

Ratings of meter used at Helena, Ark.

Date.	Meter.	Number of observations.	Registrations per revolution.	*a.*	*b.*	Range of velocities per second.	Where taken.	Remarks.
1882.						*Feet.*		
Feb. 2	Ellis No. 2	7	1	0.0615	0.158	2.9–7.6	In a pond	Without weight.
Feb. 16	do	7	1	0.0614	0.354	2.7–5.9	do	Do.
Feb. 27	do	5	1	0.0607	0.243	2.0–7.5	do	Do.
Apr 12	do	13	1	0.0609	0.474	0.8–1.9	do	Do.
May 15	do	10	1	0.0612	0.255	0.6–1.7	do	Do.
May 15	do	6	1	0.0573	0.590	3.3–5.0	do	Meter 2 inches above weight.
May 15	do	12	1	0.0636	0.217	0.0–2.9	do	Meter 4 inches above weight.
May 19	do	11	1	0.0636	0.272	0.9–1.6	do	With weight.
May 25	do	15	1	0.0678	0.047	2.8–6.2	do	Do.
June 23	do	6	1	0.0667	0.193	3.7–6.3	do	Do.
July 20	do	10	1	0.0680	0.128	2.6–6.2	do	Do.
Aug. 11	do	15	1	0.0657	0.312	1.5–5.9	do	Do.
Sept. 8	do	8	1	0.0647	0.395	2.4–6.7	do	Do.
Sept 23	do	6	1	0.0618	0.018	2.5–5.7	do	Do.
Oct. 9	do	6	1	0.0614	0.187	0.7–6.5	do	Do.

Velocities in feet per second at each tenth of depth as resulting from the velocity observations made at Helena, Ark., in 1882.

GROUP 1.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
70.2	3.87	4.34	4.54	4.30	4.27	4.42	4.20	3.54	3.22	2.73	1.96
46.5	4.48	4.42	4.34	4.43	4.46	4.38	4.45	4.18	3.80	3.10	2.50
Means=58.35	4.175	4.38	4.44	4.395	4.365	4.40	4.325	3.860	3.51	2.915	2.23

GROUP 2.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
85.0	5.22	5.56	5.60	5.27	5.05	5.16	5.13	4.44	4.24	3.75	2.97
58.3	4.62	4.55	4.45	4.18	4.12	4.05	3.49	3.63	3.39	3.06	2.47
60.0	4.05	4.78	4.78	4.71	4.66	4.65	4.58	4.53	4.41	4.02	3.86
58.4	4.65	4.75	4.58	4.53	4.45	4.27	3.86	3.76	3.45	2.97	2.53
Means=65.42	4.635	4.91	4.828	4.673	4.57	4.533	4.265	4.09	3.873	3.448	2.955

Velocities in feet per second at each tenth of depth, &c.—Continued.

GROUP 3.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
65.0	6.03	6.23	6.13	6.12	5.78	6.10	5.93	5.15	5.45	5.48	4.18
65.0	5.77	5.82	5.55	5.43	5.02	5.07	5.11	5.07	4.38	3.56	2.90
72.5	5.96	6.24	6.21	5.88	5.74	5.75	5.55	5.23	4.72	4.20	3.34
76.0	5.07	5.07	5.02	5.03	4.77	4.94	4.58	4.74	3.97	3.83	3.82
72.3	5.10	5.03	5.03	4.95	4.77	4.39	4.42	4.40	4.72	4.00	4.05
50.0	6.57	6.57	6.64	6.11	5.76	5.84	6.11	5.97	5.43	5.43	4.28
63.0	4.68	4.71	4.57	4.37	4.33	4.27	4.18	3.90	3.73	3.85	2.46
60.0	5.03	4.87	4.55	4.44	4.31	4.22	4.19	3.97	3.55	3.23	2.98
56.0	4.55	4.42	4.41	4.33	4.28	4.05	3.91	3.82	3.54	3.03	2.64
ans=65.98	5.418	5.44	5.346	5.184	5.039	4.958	4.853	4.70	4.388	4.012	3.339

GROUP 4.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
79.8	6.85	6.78	6.62	6.42	6.16	6.08	5.28	5.18	4.94	4.10	3.40
57.0	7.03	7.15	6.86	6.63	6.50	6.32	6.14	5.70	5.15	4.73	3.15
65.0	5.15	5.22	5.15	4.98	5.20	4.72	4.95	4.44	4.56	4.12	3.98
63.6	5.19	5.21	5.05	5.05	4.91	4.61	4.60	4.09	3.98	4.04	3.89
53.7	4.75	4.54	4.46	4.31	4.26	4.01	4.05	3.52	2.96	2.72	2.52
56.5	4.78	4.77	4.56	4.44	4.24	4.14	3.84	3.10	2.86	2.55	1.75
ans=62.58	5.625	5.612	5.453	5.305	5.212	4.98	4.793	[redacted]	4.075	3.71	3.092

GROUP 5.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
70.0	6.44	5.82	5.52	5.46	5.16	4.85	4.64	4.44	3.73	2.98	2.40
60.0	5.89	5.77	5.09	5.37	5.27	5.15	4.87	4.72	4.42	3.70	2.62
56.0	5.95	5.96	5.73	5.03	5.45	5.19	5.16	5.10	4.63	4.05	2.83
63.5	6.95	5.53	5.40	5.33	5.13	5.32	4.82	4.62	4.50	4.00	3.63
55.0	5.20	4.87	4.60	4.10	4.22	4.34	4.10	3.85	3.41	3.02	1.66
40.0	5.05	4.92	4.80	4.64	4.41	4.35	4.07	4.01	3.85	3.42	2.52
43.6	5.04	5.04	5.00	4.82	4.63	4.45	4.32	3.90	3.51	3.08	2.62
45.0	4.72	4.65	4.47	4.45	4.37	4.28	4.08	4.02	3.68	3.40	2.62
ans=54.01	5.541	5.308	5.151	4.986	4.83	4.741	4.519	4.333	3.97	3.456	2.612

GROUP 6.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
70.0	6.03	5.95	5.87	5.67	5.82	5.50	5.00	4.86	3.98	3.30	2.88
57.1	5.84	5.32	5.14	4.86	4.73	4.72	4.57	4.36	3.92	3.55	2.90
45.0	5.94	6.17	6.42	6.15	5.79	5.45	5.37	5.27	5.14	5.00	3.66
51.0	5.82	5.86	5.82	5.67	5.52	5.57	5.25	5.18	4.71	4.39	4.45
38.3	4.95	4.90	4.65	4.33	4.14	4.05	3.85	3.66	3.47	3.34	2.64
36.0	5.19	5.00	4.65	4.29	4.34	4.16	3.97	3.90	3.46	3.13	2.85
40.5	5.24	5.10	4.96	4.91	4.78	4.37	4.17	4.22	3.70	3.04	3.13
41.0	4.98	4.92	4.83	4.08	4.47	4.30	4.32	3.95	3.20	2.60	2.43
ans=47.36	5.436	5.403	5.293	5.058	4.949	4.776	4.563	4.425	3.941	3.544	3.116

GROUP 7.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
60.0	7.12	6.94	6.68	6.48	6.30	6.18	5.61	5.35	4.90	4.74	4.59
60.0	6.13	5.87	5.59	5.74	5.63	5.55	5.24	4.96	4.68	4.23	3.20
50.0	6.01	6.10	5.98	6.07	5.77	5.63	5.28	5.45	4.38	4.42	3.50
51.2	6.04	6.00	5.76	5.73	5.35	5.42	5.12	4.84	4.65	3.76	3.10
51.8	5.64	5.90	5.62	5.26	4.94	5.03	4.87	4.77	4.50	4.16	4.14
42.5	4.89	4.80	4.72	4.05	4.50	4.44	4.12	3.75	3.78	3.55	3.89
36.3	4.75	4.82	4.77	4.54	4.46	4.30	3.98	3.04	3.50	3.20	2.85
32.5	4.95	4.95	4.93	4.90	4.87	4.00	4.38	4.15	3.66	3.35	2.57
36.0	5.24	5.15	5.00	4.82	4.62	4.47	4.47	4.44	3.91	3.45	3.04
35.0	5.12	4.96	4.83	4.96	4.77	4.91	4.76	4.45	4.23	3.90	3.47
ans=45.53	5.591	5.549	5.388	5.275	5.129	5.062	4.803	4.58	4.237	3.876	3.385

Velocities in feet per second at each tenth of depth, &c.—**Continued.**

GROUP 8.

Depth.	Surface.	.1	.2	3	4	.5	.6	.7	.8	.9	Bottom.
59.0	6.43	6.27	6.37	6.67	6.48	6.36	5.82	5.63	5.17	4.15	3.30
55.0	7.23	6.94	7.10	7.05	6.75	6.40	5.90	5.75	5.43	4.56	3.40
53.0	7.60	7.50	7.10	6.83	6.65	6.58	6.37	5.94	5.00	4.70	4.00
50.0	6.02	6.28	5.93	5.64	5.71	5.54	5.13	4.97	4.83	4.88	3.16
48.1	5.41	5.41	5.30	5.30	5.31	5.22	5.06	4.25	3.82	3.26	2.50
47.0	6.47	6.25	6.02	5.88	5.79	5.77	5.32	4.85	4.34	3.76	3.00
47.5	6.52	6.38	5.78	5.86	6.02	6.08	5.65	5.43	5.15	4.40	3.66
41.5	5.39	5.36	5.10	4.96	4.90	4.95	4.75	4.64	4.20	3.64	3.18
30.0	5.24	5.28	5.22	4.98	4.83	4.70	4.46	4.25	4.15	3.49	2.74
32.7	5.24	5.25	5.15	5.13	4.93	4.83	4.62	4.56	4.36	3.76	3.13
Means=46.38	6.161	6.092	5.913	5.836	5.737	5.643	5.307	5.026	4.645	4.009	3.216

GROUP 9.

Depth.	Surface.	.1	.2	3	4	.5	.6	.7	.8	.9	Bottom.
54.0	6.03	6.87	6.57	6.51	6.02	6.35	6.02	5.82	5.51	4.70	3.37
48.0	6.44	6.27	6.12	5.87	5.96	5.67	5.18	4.78	4.60	4.25	3.87
50.0	6.23	6.07	6.07	6.07	5.67	5.06	5.37	5.18	4.70	4.58	2.46
50.0	6.32	6.07	5.98	5.80	5.49	5.22	5.04	4.85	4.76	4.33	2.77
29.6	4.35	4.32	4.27	4.23	4.13	3.96	3.86	3.77	3.66	3.40	2.96
30.7	4.25	4.55	4.06	4.50	4.38	4.27	4.13	3.96	3.76	3.65	3.53
33.0	4.05	4.46	4.45	4.58	4.40	4.25	3.32	4.22	3.67	3.56	2.29
Means=42.19	5.467	5.516	5.446	5.360	5.236	5.054	4.846	4.654	4.409	4.024	3.109

GROUP 10.

Depth.	Surface.	.1	.2	3	4	.5	.6	.7	.8	.9	Bottom.
61.5	6.43	6.68	6.56	6.50	6.47	6.32	5.79	4.94	4.94	4.00	3.06
47.0	6.14	6.28	6.23	6.25	6.27	5.94	5.62	5.62	5.57	5.00	2.92
39.0	4.35	4.41	4.34	4.26	4.22	4.22	3.92	3.75	3.56	3.05	2.65
29.5	3.39	3.47	3.40	3.36	3.33	3.34	3.18	3.04	3.01	2.67	2.04
20.0	3.90	3.80	3.98	3.80	3.78	3.68	3.77	3.67	3.63	3.46	3.13
26.0	4.45	4.30	4.32	4.25	4.18	4.13	4.17	4.14	4.06	3.88	3.06
Means=36.50	4.792	4.838	4.83	4.737	4.708	4.605	4.406	4.177	3.982	3.667	3.069

GROUP 11.

Depth.	Surface.	.1	.2	3	4	.5	.6	.7	.8	.9	Bottom.
38.0	4.83	4.84	4.84	4.81	4.71	4.62	4.29	3.96	3.49	3.00	2.82
49.5	4.68	5.03	4.68	4.29	4.60	4.17	3.89	4.05	3.35	2.60	1.82
28.0	3.28	3.35	3.28	3.12	3.08	3.07	2.96	2.87	2.78	2.71	2.68
26.0	3.73	3.73	3.72	3.63	3.52	3.45	3.42	3.41	3.36	3.29	3.03
24.9	3.25	3.17	2.85	2.85	2.86	2.87	2.72	2.72	2.72	2.50	2.31
27.2	3.27	3.31	3.31	3.10	2.96	2.66	2.64	2.63	2.62	2.62	2.62
25.0	3.01	3.06	3.13	3.00	2.87	3.07	3.20	2.94	2.87	2.47	2.23
Means=31.23	3.721	3.784	3.687	3.551	3.514	3.416	3.303	3.220	2.999	2.729	2.459

GROUP 12.

Depth.	Surface.	.1	.2	3	4	.5	.6	.7	.8	.9	Bottom.
27.0	4.83	4.83	4.81	4.60	4.57	4.44	4.22	3.92	[illegible]	3.57	2.48
51.0	6.17	6.32	6.24	6.14	5.82	5.72	5.25	5.28	4.88	4.80	4.56
32.6	4.38	4.66	4.65	4.25	4.15	4.07	3.60	3.63	3.51	2.81	2.17
Means=36.87	5.127	5.277	5.233	5.027	4.847	4.743	4.357	4.277	4.020	3.727	[illegible]

Velocities in feet per second for each tenth of depth, &c.—Continued.

GROUP 13.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
25.5	5.08	5.12	5.15	4.83	4.57	4.80	4.43	4.54	4.54	3.77	3.13
22.5	5.23	5.23	5.23	5.19	5.14	5.08	4.60	4.10	3.58	3.13	2.64
21.2	3.71	3.63	3.56	3.59	3.67	3.63	3.16	2.72	2.33	2.00	1.64
10.5	3.36	3.33	3.30	3.32	3.34	3.37	3.36	3.34	3.28	3.07	2.85
7.0	2.54	2.51	2.47	2.44	2.37	2.31	2.25	2.17	2.14	2.11	2.07
16.6	2.94	2.95	2.96	2.97	2.94	2.92	2.80	2.65	2.49	2.32	2.15
Means=17.22	3.810	3.795	3.778	3.723	3.672	3.685	3.433	3.253	3.060	2.733	2.413

GROUP 14.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
27.0	5.08	5.17	5.24	5.12	5.00	4.86	4.78	4.72	4.31	3.70	3.05
19.0	4.11	4.02	3.93	3.83	3.68	3.53	3.42	3.28	3.09	2.84	2.68
18.8	3.66	3.54	3.40	3.33	3.37	3.39	3.28	2.96	2.57	2.25	1.96
26.5	4.45	4.43	4.43	4.46	4.44	4.11	3.87	3.87	3.73	3.48	3.25
Means=22.82	4.325	4.290	4.250	4.185	4.123	3.973	3.838	3.708	3.425	3.068	2.735

4.—Hays' Landing, Mississippi.

Ratings of meters used at Hays Landing, Miss:

Date.	Meter.	Number of observations.	Registrations per revolution.	a	b	Range of velocities.	Where taken.
1882.						Feet per second.	
March 18	2	19	1	0.0576	0.6083	1.41-7.69	In a pond.
April 2	2	18	1	0.0573	0.5528	1.23-5.80	Do.
May 27	2	20	1	0.0576	0.6809	1.38-7.84	Do.
October 9	4	30	1	0.0517	0.5167	1.02-7.45	Do.

Velocities in feet per second at each tenth of depth as resulting from the velocity observations made at Hays Landing, Miss., in 1882.

STATION 2.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
22.0	3.46	3.55	3.64	3.60	3.51	3.42	3.35	3.26	3.13	3.00
23.0	3.57	3.57	3.57	3.53	3.48	3.43	3.37	3.32	3.27	3.23
23.0	3.34	3.45	3.55	3.49	3.38	3.31	3.26	3.15	2.99	2.88
22.0	3.23	3.23	3.23	3.29	3.28	3.17	3.14	3.11	2.88	2.76
21.0	3.34	3.34	3.34	3.31	3.27	3.23	3.23	3.23	3.01	2.76
21.4	3.92	3.86	3.82	3.72	3.56	3.43	3.33	3.24	3.23	3.23
32.0	3.23	3.15	3.05	2.91	2.94	2.99	2.99	3.21	3.38	2.92
Means = 23.49	3.441	3.450	3.457	3.407	3.346	3.283	3.239	3.217	3.127	2.967

STATION 4.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
68.0	4.15	4.63	4.85	4.87	5.10	5.35	4.74	4.36	4.32	4.00
70.0	4.73	4.75	4.79	4.75	4.68	4.67	4.42	4.53	4.45	4.35
66.0	4.85	4.93	5.08	5.18	5.27	5.12	4.97	4.85	4.85	4.74
68.0	4.61	4.61	4.57	4.50	4.47	4.40	4.37	4.33	4.16	4.15
60.0	4.73	4.75	4.76	4.76	4.85	4.61	4.59	4.46	4.46	4.59
62.0	5.08	5.08	4.97	4.67	4.84	4.80	4.52	4.32	3.95	3.66
60.9	6.70	7.16	7.16	7.16	6.76	6.67	6.40	6.23	6.23	6.02
58.5	4.04	4.03	4.32	4.04	3.91	3.72	3.92	3.84	3.69	3.33
55.5	3.69	3.85	4.15	4.07	3.92	3.92	3.92	3.92	3.72	3.69
55.0	3.69	3.69	3.69	3.72	3.85	3.81	3.56	3.38	3.16	2.98
51.0	3.23	3.00	3.23	3.26	3.54	3.25	3.30	2.98	2.88	2.85
49.8	3.11	3.00	2.99	3.22	3.23	3.16	3.12	3.22	2.77	2.43
40.0	1.34	1.34	1.28	1.20	1.14	1.14	1.06	1.03	1.00	0.92
50.1	3.69	3.69	3.69	3.69	3.69	3.57	3.57	3.46	3.34	3.23
42.5	2.42	2.52	2.67	2.64	2.44	2.30	2.30	2.30	2.30	2.07
44.2	2.53	2.53	2.53	2.53	2.48	2.37	2.27	2.18	2.17	2.09
43.0	2.76	2.76	2.60	2.53	2.49	2.39	2.29	2.18	2.08	2.07
44.0	2.76	2.76	2.76	2.76	2.71	2.65	2.65	2.59	2.53	2.53
44.2	2.65	2.65	2.56	2.53	2.53	2.44	2.30	2.30	2.29	2.19
43.0	2.88	2.78	2.76	2.70	2.60	2.53	2.53	2.53	2.44	2.24
41.9	2.76	2.76	2.76	2.76	2.72	2.58	2.30	2.27	2.22	2.18
43.8	2.50	2.40	2.56	2.59	2.54	2.48	2.26	2.17	2.17	2.09
44.8	2.17	2.37	2.22	2.10	2.01	1.86	1.72	1.60	1.43	1.34
42.9	2.17	2.17	2.10	2.07	1.98	1.92	2.05	1.96	1.79	1.65
41.1	1.96	1.96	2.10	2.17	2.14	2.06	1.97	1.81	1.76	1.76
41.1	2.28	2.19	2.17	2.12	2.04	1.95	1.87	1.79	1.70	1.65
39.5	2.17	2.09	2.13	2.13	1.99	1.58	1.55	1.55	1.52	1.45
39.1	1.76	1.92	1.96	1.96	1.95	1.87	1.79	1.76	1.73	1.65
38.0	2.38	2.30	2.22	2.17	2.17	2.09	2.01	1.90	1.75	1.57
38.1	2.38	2.38	2.27	2.17	2.16	2.00	1.96	1.93	1.86	1.86
39.1	1.96	2.05	2.01	1.96	1.95	1.87	1.86	1.82	1.75	1.65
37.0	2.59	2.59	2.64	2.67	2.69	2.48	2.44	2.38	2.38	2.38
38.1	2.17	2.17	2.17	2.14	2.06	1.82	1.64	1.55	1.54	1.46
39.5	1.96	1.96	1.96	1.96	1.96	1.96	1.89	1.86	1.83	1.76
39.4	2.07	2.07	2.07	2.03	1.95	1.87	1.79	1.70	1.62	1.55
37.1	1.96	1.96	1.96	2.01	2.16	2.02	1.96	1.94	1.87	1.86
39.5	1.65	1.74	1.76	1.76	1.76	1.76	1.76	1.76	1.73	1.65
38.1	1.96	1.96	1.86	1.70	1.55	1.55	1.55	1.52	1.44	1.36
38.5	2.17	2.01	1.85	1.79	1.85	1.78	1.63	1.55	1.53	1.46
38.7	2.17	2.17	2.17	2.10	1.94	1.77	1.82	1.66	1.34	1.34
37.9	2.07	2.15	2.06	2.02	2.06	1.91	1.81	1.73	1.64	1.57
37.1	1.76	1.76	1.76	1.76	1.76	1.68	1.65	1.65	1.65	1.58
38.0	1.96	1.96	1.91	1.86	1.86	1.78	1.76	1.73	1.64	1.57
38.9	2.07	2.07	2.07	2.03	1.94	1.78	1.69	1.61	1.55	1.55
37.5	2.17	2.10	2.07	2.04	1.96	1.80	1.81	1.73	1.65	1.58
38.1	2.07	1.99	1.96	1.99	2.06	1.82	1.76	1.72	1.64	1.56
37.5	2.07	2.07	2.07	2.02	1.86	1.86	1.86	1.88	1.76	1.76
38.0	2.38	2.30	2.17	2.04	1.96	1.96	1.90	1.83	1.75	1.67
39.5	2.28	2.36	2.31	2.24	2.11	1.78	1.88	1.81	1.70	1.45
38.7	2.38	2.38	2.38	2.38	2.37	2.29	2.28	2.24	2.09	1.77
39.1	2.28	2.20	2.17	2.13	1.97	1.87	1.86	1.86	1.86	1.86
39.4	2.17	2.26	2.28	2.20	2.05	1.85	1.80	1.86	1.86	1.86
42.3	2.28	2.28	2.20	2.17	2.17	2.17	2.16	2.06	1.99	1.80
42.0	2.48	2.48	2.41	2.38	2.42	2.46	2.38	2.29	2.28	2.20
41.8	2.28	2.36	2.31	2.33	2.35	2.26	2.17	1.99	1.80	1.80
41.5	2.48	2.48	2.41	2.38	2.41	2.46	2.38	2.30	2.28	2.22
Means = 44.61	2.716	2.733	2.729	2.698	2.668	2.571	2.495	2.423	2.339	2.34[illegible]

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 6.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
62.8	4.44	5.37	5.28	5.93	6.17	5.78	5.13	4.84	4.54	4.16
68.0	5.37	5.18	5.08	5.42	5.74	5.68	5.54	5.15	4.92	4.00
66.0	4.73	4.87	4.65	4.78	5.45	5.40	5.20	5.06	4.89	4.75
67.5	5.19	5.18	5.18	5.60	6.17	5.89	5.51	4.95	4.52	4.06
65.0	5.08	5.02	4.92	5.07	5.08	5.18	5.22	5.50	4.98	4.62
65.2	5.08	5.15	4.94	4.75	4.70	4.96	5.04	4.84	4.73	4.32
63.5	4.61	5.24	4.83	4.81	4.75	4.88	4.73	4.43	4.15	4.24
63.0	3.92	4.04	4.19	4.28	4.16	4.65	4.40	4.04	3.67	3.38
60.0	4.15	4.15	4.15	4.02	3.92	4.04	3.97	4.05	3.84	3.72
59.5	3.92	4.07	4.06	3.92	3.92	3.92	3.91	3.76	3.58	3.31
60.0	3.46	3.57	3.62	3.69	3.97	3.80	3.64	3.37	3.09	2.82
55.8	3.69	3.69	3.58	3.33	3.85	3.91	3.73	3.51	3.26	2.89
52.5	3.46	3.46	3.62	3.88	3.72	3.74	3.46	3.14	2.94	3.83
53.4	3.69	3.69	3.69	3.69	3.66	3.57	3.52	3.46	3.46	3.33
45.0	2.99	2.99	3.08	2.94	3.82	2.76	2.72	2.65	2.64	2.52
46.0	2.76	2.87	2.69	2.65	2.57	2.53	2.53	2.53	2.49	2.36
47.0	3.46	3.46	3.36	3.25	3.23	3.23	3.15	3.04	2.94	2.82
46.8	2.99	3.10	3.21	3.04	2.99	2.92	2.81	2.76	2.71	2.60
46.0	2.99	2.99	2.91	2.88	2.88	2.81	2.77	2.62	2.53	2.53
45.2	2.99	3.10	3.11	3.03	2.78	2.65	2.65	2.62	2.47	2.14
47.9	2.69	2.69	2.60	2.59	2.50	2.48	2.41	2.31	2.28	2.21
46.8	3.00	3.00	2.92	2.65	2.44	2.32	2.22	2.12	2.03	1.90
43.5	2.69	2.60	2.66	2.63	2.54	2.37	2.17	2.17	2.17	1.96
45.5	2.48	2.58	2.59	2.51	2.42	2.33	2.33	2.34	2.25	2.17
45.0	2.59	2.40	2.38	2.38	2.38	2.38	2.30	2.11	1.88	1.55
43.0	2.59	2.59	2.51	2.42	2.34	2.22	2.05	1.96	1.78	1.68
42.1	2.79	2.79	2.72	2.69	2.58	2.38	2.38	2.38	2.23	2.11
43.0	2.79	2.63	2.52	2.43	2.29	2.14	2.08	2.17	2.17	2.10
42.5	3.00	2.82	2.79	2.68	2.51	2.36	2.28	2.28	2.19	2.17
42.8	2.79	2.79	2.79	2.73	2.69	2.66	2.58	2.48	2.40	2.31
42.0	1.55	1.55	1.55	1.61	1.62	1.51	1.34	1.34	1.28	1.19
42.1	2.69	2.60	2.69	2.64	2.59	2.59	2.59	2.59	2.52	2.42
41.4	2.59	2.59	2.66	2.54	2.41	2.47	2.38	2.30	2.21	2.07
42.0	2.59	2.59	2.59	2.59	2.55	2.48	2.48	2.39	2.31	2.22
41.8	2.59	2.59	2.52	2.43	2.35	2.28	2.28	2.28	2.21	2.10
42.0	2.48	2.48	2.48	2.48	2.44	2.34	2.17	2.08	1.99	1.96
40.1	2.59	2.59	2.59	2.59	2.57	2.48	2.48	2.48	2.44	2.25
40.9	2.79	2.63	2.59	2.54	2.45	2.37	2.29	2.35	2.27	2.10
40.8	2.38	2.38	2.32	2.33	2.33	2.16	1.98	1.96	1.91	1.86
40.4	2.38	2.38	2.24	2.17	2.17	2.17	2.17	1.90	1.57	1.25
42.4	2.28	2.28	2.35	2.38	2.29	2.14	2.06	1.97	1.81	1.70
39.8	2.59	2.59	2.53	2.45	2.33	2.07	1.91	1.75	1.62	1.53
39.9	2.48	2.57	2.59	2.55	2.46	2.38	2.30	2.22	2.09	1.87
40.1	2.48	2.48	2.55	2.51	2.34	2.17	2.09	2.00	1.92	1.83
40.0	2.79	2.71	2.63	2.59	2.57	2.48	2.40	2.38	2.34	2.28
40.2	2.48	2.40	2.44	2.44	2.36	2.28	2.11	2.00	1.92	1.86
40.9	2.48	2.48	2.48	2.48	2.45	2.38	2.38	2.38	2.38	2.32
40.2	2.79	2.71	2.69	2.60	2.48	2.48	2.40	2.32	2.23	2.13
41.5	2.59	2.50	2.48	2.43	2.41	2.47	2.38	2.38	2.25	2.07
43.1	2.79	2.79	2.79	2.79	2.75	2.69	2.67	2.59	2.59	2.43
40.7	2.90	2.81	2.73	2.69	2.67	2.59	2.49	2.48	2.38	2.22
41.5	2.90	2.81	2.72	2.64	2.59	2.57	2.50	2.48	2.42	2.20
44.0	2.79	2.79	2.79	2.79	2.74	1.65	2.59	2.52	2.16	2.07
43.8	3.00	3.00	2.93	2.96	2.90	2.75	2.69	2.65	2.38	2.29
43.0	2.90	2.99	3.00	3.00	2.91	2.70	2.50	2.59	2.41	2.23
43.7	3.00	3.18	3.21	3.21	3.11	2.92	2.77	2.68	2.59	2.50
s = 47.48	3.112	3.136	3.103	3.091	3.090	2.991	2.908	2.816	2.677	2.527

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 8.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
64.0	5.31	5.51	5.52	5.84	6.02	6.09	6.02	5.90	5.89	5.83
69.8	5.66	5.42	5.50	5.75	5.60	5.76	5.75	5.87	5.89	5.87
68.0	5.77	5.45	5.14	5.35	5.76	5.71	5.31	5.19	5.08	4.80
63.0	4.96	5.04	5.42	5.72	5.32	5.41	5.08	4.69	4.58	4.31
61.9	4.85	5.02	5.06	5.96	6.02	5.96	5.49	5.15	4.85	5.29
60.5	4.38	4.38	4.43	4.57	4.82	4.51	4.22	4.16	3.76	3.48
58.8	4.15	4.24	4.70	5.07	4.80	4.61	4.38	4.33	4.15	4.02
57.0	4.38	4.36	4.15	4.20	4.27	4.35	4.38	4.15	3.68	3.53
49.5	4.38	4.61	4.61	4.38	4.16	4.15	4.36	4.18	4.16	4.05
45.5	3.46	3.46	3.46	3.64	3.62	3.51	3.46	3.42	3.32	3.22
44.2	3.69	3.69	3.69	3.69	3.63	3.57	3.53	3.46	3.46	3.46
43.0	3.69	3.59	3.57	3.57	3.66	3.72	3.62	3.79	3.59	3.57
45.1	3.23	3.65	3.87	3.75	3.62	3.63	3.60	3.53	3.63	3.30
40.9	3.80	3.72	3.76	3.86	3.92	3.91	3.82	3.72	3.62	3.27
42.0	3.11	3.40	3.32	3.36	3.38	3.22	3.11	3.11	2.96	2.83
42.8	3.92	3.82	3.80	3.73	3.64	3.47	3.23	3.23	2.83	2.68
44.0	3.41	3.41	3.33	3.30	3.16	3.18	2.97	2.88	2.79	2.79
44.1	3.62	3.44	3.57	3.35	3.21	3.08	2.87	2.73	2.48	2.30
43.2	3.31	3.31	3.24	3.21	3.21	3.14	3.00	2.99	2.81	2.69
41.0	3.41	3.25	3.21	3.21	3.21	3.19	3.02	2.93	2.73	2.59
39.9	3.00	3.00	3.00	3.00	3.00	3.00	2.92	2.90	2.86	2.79
38.0	2.79	2.64	2.75	2.93	2.98	2.75	2.69	2.61	2.36	2.19
39.9	2.59	2.59	2.65	2.69	2.67	2.59	2.59	2.59	2.51	2.38
39.5	2.69	2.69	2.63	2.63	2.66	2.40	2.31	2.22	2.14	2.05
40.5	3.31	2.98	2.83	2.79	2.72	2.48	2.48	2.41	2.33	2.23
38.5	3.10	3.02	2.89	2.79	2.78	2.71	2.63	2.59	2.57	2.49
39.2	1.96	1.81	1.87	1.88	1.75	1.66	1.58	1.55	1.52	1.44
39.5	2.79	2.79	2.79	2.79	2.77	2.70	2.69	2.64	2.56	2.48
40.5	3.00	3.17	3.21	3.21	3.14	2.89	2.81	2.79	2.74	2.69
39.9	2.59	2.91	2.75	2.59	2.62	2.69	2.77	2.67	2.54	2.46
39.9	2.79	2.96	3.00	2.92	2.75	2.59	2.59	2.41	2.24	2.17
41.0	2.79	2.79	2.79	2.79	2.76	2.08	2.60	2.59	2.53	2.40
38.5	2.79	2.79	2.79	2.78	2.58	2.60	2.55	2.63	2.46	2.39
38.5	3.00	3.00	2.95	2.87	2.79	2.70	2.79	2.75	2.67	2.60
37.1	2.79	2.87	2.84	2.70	2.40	2.53	2.54	2.48	2.48	1.86
37.9	2.90	2.90	2.85	2.82	2.89	2.66	2.48	2.33	2.36	2.13
37.5	2.59	2.74	2.89	2.88	2.59	2.50	2.59	2.54	2.38	2.31
41.0	3.10	3.02	3.06	2.95	2.82	2.57	2.41	2.38	2.26	2.11
40.6	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.03	3.00	2.90
40.3	3.21	3.21	3.14	3.06	2.98	2.90	2.81	2.66	2.50	2.29
40.0	3.00	3.00	2.87	2.79	2.77	2.69	2.61	2.52	2.44	2.38
40.9	2.90	2.81	2.86	2.85	2.79	2.78	2.70	2.62	2.53	2.48
40.0	3.00	3.00	3.00	2.96	2.90	2.90	2.73	2.63	2.55	2.43
40.0	3.21	3.21	3.21	3.13	2.98	2.90	2.86	2.73	2.65	2.59
40.5	3.00	3.00	3.06	3.10	3.08	3.00	3.00	2.86	2.74	2.62
41.1	3.21	3.21	3.21	3.16	3.07	2.99	2.91	2.82	2.68	2.52
41.2	3.21	3.21	3.14	3.05	3.00	3.00	3.00	2.92	2.78	2.62
40.9	3.31	3.31	3.25	3.21	3.18	3.09	3.01	2.85	2.63	2.42
41.7	3.62	3.44	3.41	3.32	3.17	3.08	3.00	2.92	2.82	2.74
45.0	3.62	3.43	3.41	3.34	3.37	3.36	3.23	3.04	2.90	2.90
41.5	3.62	3.54	3.45	3.41	3.38	3.31	3.31	3.14	3.10	2.91
43.1	3.72	3.72	3.65	3.62	3.57	3.45	3.27	3.08	3.01	2.92
Means = 44.46	3.428	3.435	3.434	3.454	3.405	3.336	3.246	3.160	3.041	2.917

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 10.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
82.0	5.08	6.30	6.70	6.70	6.47	6.08	5.63	4.97	4.56	4.00
74.5	4.61	4.85	4.85	4.95	4.75	5.50	4.61	4.64	4.41	4.05
77.2	4.61	4.61	4.97	5.08	5.13	5.15	4.58	5.14	4.61	4.41
76.0	4.38	4.75	5.33	6.00	5.50	5.35	5.46	4.69	4.38	3.98
68.0	4.38	4.32	4.30	4.58	4.44	4.58	4.25	4.11	3.83	3.69
70.5	4.85	4.85	4.85	4.85	4.85	4.72	4.56	4.40	4.24	4.08
69.5	4.61	4.95	4.70	5.16	5.21	5.09	5.15	5.00	4.84	4.67
68.9	4.85	4.70	4.67	4.83	4.67	4.61	4.50	4.50	4.38	4.22
64.0	4.38	4.38	4.38	4.29	4.28	4.38	4.31	4.27	4.24	4.15
63.0	4.27	4.27	4.27	4.27	4.27	4.23	4.15	4.15	4.14	4.00
63.0	4.[illegible]5	4.42	4.21	4.35	4.16	4.23	4.15	4.07	3.92	3.87
61.5	3.46	4.13	4.14	4.49	4.61	4.47	4.34	4.27	3.97	3.65
59.2	3.92	3.16	4.15	4.15	4.15	4.15	4.15	4.12	3.98	3.83
61.7	3.92	3.89	3.80	3.88	3.92	4.11	3.92	3.77	3.52	3.20
64.0	3.83	3.72	3.78	3.83	3.72	3.68	3.55	3.41	3.39	3.31
65.5	3.62	3.62	3.62	3.62	3.84	3.84	3.63	3.50	3.31	3.21
62.2	3.62	3.54	3.57	3.59	3.62	3.62	3.57	3.52	3.23	3.08
62.5	3.93	3.67	3.72	3.78	4.03	3.82	3.66	3.53	3.52	3.41
61.5	3.62	3.46	3.02	3.62	3.62	3.41	3.37	3.31	3.23	3.21
53.3	3.21	3.21	3.21	3.23	3.33	3.41	3.33	2.93	2.53	2.43
50.9	3.00	3.21	3.21	3.21	3.20	3.10	3.10	3.09	3.00	3.00
58.0	3.21	3.21	3.21	3.21	3.21	3.21	3.11	3.09	3.00	2.91
55.0	3.21	3.21	3.21	3.00	3.00	2.90	2.79	2.65	2.59	2.49
56.0	3.21	3.21	3.21	3.17	3.10	3.10	3.03	3.00	2.80	2.79
62.4	2.90	2.90	2.85	2.79	2.79	2.77	2.69	2.62	2.59	2.54
61.8	3.21	3.21	3.21	3.21	3.11	3.10	3.10	3.10	3.01	2.76
54.0	3.21	3.21	3.21	3.18	3.10	3.10	2.95	2.79	2.66	2.51
59.0	3.21	3.21	3.21	3.21	3.13	3.10	3.09	3.00	2.96	2.83
56.0	3.21	3.21	3.21	3.17	3.10	3.10	3.03	3.00	2.90	2.78
58.5	3.21	3.21	3.21	3.21	3.21	3.12	3.10	3.08	3.00	2.95
59.8	3.21	3.20	3.21	3.21	3.12	3.00	2.98	2.86	2.79	2.64
56.0	3.21	3.21	3.21	3.17	3.10	3.04	2.85	2.79	2.69	2.46
59.8	3.10	3.10	3.06	3.00	3.00	3.00	2.90	2.86	2.79	2.64
58.5	3.00	3.00	3.00	2.95	2.90	2.90	2.79	2.79	2.75	2.64
58.8	2.90	2.92	2.93	2.79	2.79	2.79	2.59	2.61	2.65	2.53
59.8	3.21	3.21	3.21	3.21	3.21	3.10	3.02	3.00	2.88	2.79
56.0	3.21	3.21	3.21	3.21	3.21	3.16	3.10	3.10	3.02	3.00
50.0	3.21	3.21	3.21	3.21	3.10	3.10	2.79	2.79	2.59	2.48
59.0	3.21	3.21	3.21	3.21	3.13	3.10	3.00	2.95	2.79	2.73
52.5	3.00	3.01	3.10	3.09	3.00	2.98	2.90	2.86	2.79	2.75
59.2	3.10	3.10	3.10	3.10	3.10	3.01	3.00	2.97	2.90	2.83
57.0	3.31	3.31	3.31	3.31	3.25	3.21	3.03	3.00	2.89	2.74
59.0	3.41	3.41	3.37	3.31	3.24	3.21	3.10	3.07	2.91	2.73
59.2	3.41	3.41	3.41	3.41	3.34	3.31	3.21	3.18	3.05	2.80
55.0	3.41	3.41	3.41	3.41	3.37	3.31	3.25	3.21	3.04	2.79
57.9	3.52	3.44	3.55	3.36	3.31	3.23	3.21	3.10	3.07	2.87
59.9	3.62	3.62	3.58	3.46	3.33	3.31	3.21	3.17	3.10	3.02
59.1	3.62	3.64	3.65	3.52	3.44	3.41	3.31	3.28	3.16	3.04
59.0	3.72	3.72	3.72	3.67	3.62	3.62	3.52	3.49	3.32	3.14
59.2	3.83	3.83	3.79	3.72	3.65	3.62	3.62	3.62	3.57	3.32
Means = 61.07	3.622	3.657	3.696	3.719	3.675	3.649	3.525	3.448	3.310	3.079

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 12.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
86.2	5.54	6.07	5.66	6.04	5.83	5.23	5.54	5.28	4.90	4.73
85.0	4.85	5.03	5.02	5.36	6.00	5.48	5.25	5.28	4.78	4.61
76.0	5.54	5.18	5.07	4.90	4.85	4.85	4.73	4.53	4.38	4.23
68.9	4.27	4.20	4.18	4.15	4.21	4.27	4.35	4.27	4.15	4.06
68.4	4.50	4.52	4.38	4.25	4.15	4.15	4.15	4.10	3.93	3.80
68.2	4.38	4.38	4.30	4.38	4.38	4.38	4.27	4.21	4.15	4.01
69.0	4.15	4.23	4.15	4.25	4.27	4.17	4.12	3.96	3.80	3.69
68.4	4.15	4.15	4.15	4.38	4.44	4.40	4.15	4.02	3.70	3.42
68.2	4.15	4.19	4.27	4.27	4.22	4.15	4.13	3.98	3.92	3.77
68.4	4.04	4.00	3.92	3.92	3.92	3.92	3.87	3.74	3.69	3.65
71.3	4.03	3.83	3.83	3.83	3.76	3.62	3.62	3.52	3.41	3.33
69.0	3.83	3.83	3.83	3.83	3.83	3.73	3.69	3.62	3.52	3.33
64.5	3.72	3.72	3.72	3.72	3.72	3.72	3.72	3.52	3.35	3.21
69.0	3.83	3.83	3.75	3.72	3.72	3.63	3.62	3.55	3.52	3.41
69.0	3.83	3.83	3.75	3.72	3.67	3.62	3.60	3.52	3.41	3.37
67.4	3.41	3.41	3.34	3.31	3.35	3.34	3.21	3.16	3.10	3.00
65.9	3.41	3.68	3.69	3.57	3.47	3.50	3.22	2.97	2.90	2.81
65.8	3.41	3.41	3.35	3.41	3.41	3.29	3.21	2.98	2.84	2.71
65.8	3.21	3.35	3.34	3.41	3.36	3.03	2.80	2.69	2.64	2.59
64.5	3.52	3.28	3.27	3.31	3.29	3.21	3.21	3.10	3.07	3.00
65.1	3.41	3.31	3.31	3.31	3.21	3.15	3.02	2.99	2.90	2.82
60.4	3.62	3.62	3.62	3.62	3.45	3.48	3.41	3.41	3.41	3.32
64.5	3.41	3.58	3.35	3.21	3.21	3.21	3.05	2.99	2.90	2.83
66.9	3.41	3.45	3.52	3.41	3.41	3.34	3.31	3.27	3.21	3.10
66.5	3.41	3.41	3.41	3.41	3.31	3.31	3.31	3.21	3.21	3.10
66.0	3.41	3.34	3.48	3.41	3.38	3.25	3.21	2.95	2.68	2.49
61.4	3.41	3.45	3.21	3.07	3.00	2.97	2.75	2.69	2.61	2.59
64.1	3.41	3.21	3.27	3.13	2.97	2.88	2.93	2.79	2.67	2.53
62.1	3.31	3.41	3.36	3.21	3.31	3.19	2.96	2.94	2.80	2.67
65.4	3.31	3.21	3.27	3.22	3.21	3.21	3.21	2.81	2.95	2.84
60.8	3.21	3.33	3.37	3.25	3.21	3.09	3.27	3.29	2.79	2.70
59.5	3.72	3.50	3.45	3.46	3.49	3.34	3.21	3.17	3.05	3.00
61.0	3.52	3.52	3.52	3.45	3.41	3.41	3.38	3.26	3.05	2.92
63.5	3.31	3.34	3.41	3.25	3.09	2.97	2.83	2.79	2.69	2.56
65.0	3.31	3.31	3.25	3.21	3.10	3.06	3.12	2.00	3.00	2.85
66.1	3.41	3.31	3.25	3.21	3.21	3.14	3.10	2.87	2.73	2.69
65.2	3.31	3.31	3.31	3.31	3.21	3.15	3.10	3.00	2.91	2.56
61.3	3.41	3.50	3.37	3.38	3.41	3.30	3.25	3.37	3.32	2.78
66.0	3.62	3.62	3.42	3.41	3.28	3.40	3.42	3.14	2.84	2.70
67.1	3.52	3.55	3.55	3.52	3.41	3.34	3.31	3.28	3.03	2.88
66.9	3.62	3.62	3.48	3.52	3.52	3.52	3.52	3.30	2.96	2.79
65.5	3.72	3.67	3.75	3.62	3.62	3.57	3.42	3.50	3.26	2.85
67.4	4.03	3.90	3.83	3.83	3.79	3.72	3.64	3.77	3.43	3.20
67.5	3.72	3.87	3.78	3.72	3.64	3.57	3.43	3.58	3.27	3.10
64.0	3.83	3.93	3.99	3.86	3.62	3.62	3.62	3.52	3.57	3.25
68.1	4.14	3.93	3.86	3.83	3.72	3.72	3.78	3.67	3.42	3.15
Means = 66.87	3.767	3.768	3.727	3.708	3.675	3.600	3.544	3.447	3.300	3.152

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 14.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
82.2	5.54	6.23	5.77	5.77	6.23	5.95	5.57	5.43	5.27	5.08
78.5	5.77	6.04	6.47	6.32	6.23	5.84	5.21	4.85	5.12	5.04
74.6	5.54	5.61	5.77	6.12	6.23	5.85	5.58	5.20	4.86	4.67
73.5	5.31	5.31	5.09	5.25	6.31	5.77	5.59	5.23	4.92	4.78
69.0	5.54	5.72	5.22	4.38	4.38	4.16	4.38	4.23	4.14	3.19
70.9	5.54	5.12	5.03	4.98	5.00	4.95	4.73	4.61	4.38	4.28
71.2	5.08	5.20	5.27	5.02	4.85	5.06	5.63	5.53	4.44	4.34
68.0	5.08	4.93	4.92	5.05	4.85	4.85	4.64	4.73	4.40	4.23
60.3	4.38	4.27	4.31	4.52	4.52	4.38	4.24	4.15	4.00	3.82
62.3	4.15	4.13	4.10	4.15	4.15	4.13	3.98	3.83	3.70	3.54
62.4	4.38	4.47	4.27	4.49	4.38	4.30	4.27	4.07	3.92	3.78
62.1	4.38	4.38	4.38	4.30	4.27	4.17	4.22	4.08	4.04	3.92
58.7	4.15	4.15	4.15	4.15	4.23	4.37	4.15	4.15	3.99	3.66
59.3	4.04	4.18	4.28	4.15	3.97	4.14	4.34	4.01	3.75	3.35
58.5	4.38	4.19	4.38	4.38	4.31	4.27	4.15	4.11	3.88	3.74
57.5	4.15	4.04	4.04	4.04	3.97	3.92	3.92	3.91	3.80	3.78
61.1	4.24	4.12	3.99	3.86	3.83	3.83	3.83	3.77	3.64	3.62
61.9	4.03	3.80	3.67	3.62	3.52	3.41	3.50	3.48	3.23	3.02
61.0	3.72	3.72	3.72	3.65	3.62	3.71	3.62	3.57	3.48	3.21
61.0	3.83	3.83	3.74	3.55	3.52	3.60	3.48	3.62	3.54	3.41
60.5	4.03	3.79	3.58	3.72	3.65	3.53	3.59	3.47	3.27	3.11
59.4	3.62	3.58	3.37	3.37	3.49	3.42	3.30	3.21	3.16	3.03
57.9	3.62	3.59	3.48	3.52	3.41	3.41	3.32	3.19	2.97	2.85
57.0	3.62	3.38	3.27	3.33	3.21	3.28	3.23	3.00	2.89	2.76
58.9	3.31	3.31	3.31	3.26	3.21	3.21	3.10	3.08	3.00	2.87
58.4	3.31	3.31	3.31	3.26	3.21	3.03	3.00	2.88	2.79	2.69
58.0	3.21	3.21	3.18	3.10	3.17	3.04	2.90	2.78	2.69	2.65
60.2	3.41	3.39	3.35	3.41	3.33	3.21	3.10	3.06	3.00	2.92
62.5	3.21	3.21	3.31	3.41	3.21	3.18	3.10	3.03	3.00	2.98
61.1	3.31	3.31	3.31	3.24	3.21	3.20	3.10	3.05	3.00	2.90
61.2	3.62	3.50	3.41	3.34	3.40	3.40	3.31	3.25	3.21	3.08
61.0	3.62	3.50	3.41	3.41	3.32	3.31	3.28	3.21	3.21	3.10
61.2	3.31	3.31	3.27	3.21	3.21	3.09	3.00	2.94	2.81	2.59
61.1	3.31	3.29	3.21	3.21	3.11	3.10	3.07	3.00	2.84	2.48
60.8	3.21	3.21	3.16	3.10	3.10	2.99	2.90	2.84	2.72	2.60
59.4	3.10	3.10	3.10	3.10	3.10	3.10	3.00	2.97	2.85	2.79
60.0	3.00	3.00	3.00	3.00	3.00	2.90	2.90	2.85	2.79	2.63
60.2	3.41	3.25	3.41	3.41	3.41	3.31	3.21	3.16	3.10	3.02
60.0	3.31	3.29	3.17	3.10	3.19	3.21	2.98	2.82	2.63	2.42
60.0	3.10	3.10	3.10	3.02	3.17	3.21	2.95	2.65	2.53	2.40
60.1	3.41	3.31	3.31	3.25	3.12	3.10	3.08	3.00	2.75	2.51
59.4	3.31	3.29	3.17	3.22	3.31	3.02	2.90	2.87	2.69	2.51
55.2	3.41	3.51	3.41	3.41	3.37	3.26	3.14	3.10	3.02	3.00
60.2	3.41	3.29	3.25	3.37	3.33	3.21	2.95	2.84	2.71	2.50
61.2	3.41	3.31	3.27	3.21	3.11	3.11	3.14	2.96	2.87	2.59
59.9	3.41	3.58	3.45	3.46	3.50	3.41	3.17	2.96	2.90	2.90
60.0	3.62	3.52	3.48	3.48	3.52	3.62	3.46	3.17	3.04	2.96
62.1	3.62	3.62	3.62	3.55	3.52	4.41	3.41	3.34	3.31	3.19
63.5	3.62	3.65	3.67	3.45	3.42	3.41	3.21	3.21	3.10	3.06
62.9	3.83	3.70	3.57	3.60	3.52	3.49	3.36	3.21	3.18	2.90
61.5	3.83	3.72	3.66	3.55	3.61	3.38	3.26	3.14	3.10	2.78
s = 62.33	3.917	3.894	3.846	3.820	3.820	3.749	3.656	3.545	3.405	3.255

Velocities in feet per second at each tenth of depth, &c.—**Continued.**

STATION 16.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
80.0	6.81	7.55	7.84	8.03	7.65	6.93	7.36	7.72	6.73	5.82
80.8	7.39	7.04	6.96	6.73	6.75	7.05	7.16	6.86	6.48	6.23
79.0	6.93	6.86	6.93	7.44	6.93	6.93	6.58	6.27	5.72	5.00
78.8	7.39	6.85	7.05	6.30	6.28	6.66	6.34	5.90	5.70	5.23
77.9	6.70	7.06	7.67	7.77	7.39	7.20	6.62	6.25	6.43	5.70
75.0	6.47	6.64	6.70	6.98	6.93	6.47	6.81	6.70	6.93	5.99
73.2	6.23	6.23	6.23	6.23	6.23	6.32	6.05	5.60	5.55	5.27
72.5	6.00	5.89	6.19	6.23	6.62	5.67	5.63	5.31	5.17	4.84
70.7	5.77	5.65	5.60	5.62	5.92	5.74	5.31	5.11	4.92	4.67
62.0	5.08	5.31	5.31	5.47	5.54	5.36	4.61	4.45	4.38	4.12
63.0	5.08	5.20	5.02	4.98	5.31	5.23	4.95	4.65	4.35	4.12
57.0	3.92	3.92	3.92	3.87	3.74	3.54	3.28	3.11	2.87	2.76
53.0	4.04	4.37	4.15	4.13	4.02	3.88	3.76	3.69	3.57	3.46
58.9	4.38	4.36	4.23	4.10	3.95	4.03	3.92	3.77	3.64	3.57
56.0	3.92	3.92	3.92	3.96	3.98	3.92	3.87	3.69	3.47	3.40
56.0	3.92	4.23	4.02	3.97	3.98	4.06	4.08	4.04	3.82	3.68
57.0	4.15	3.89	3.72	3.75	3.82	3.84	3.80	3.57	3.53	3.14
55.7	3.92	3.92	3.92	3.92	3.82	3.69	3.69	3.69	3.58	3.57
49.5	4.03	3.93	3.83	3.73	3.72	3.63	3.53	3.42	3.82	3.31
53.0	3.83	3.71	3.61	3.50	3.44	3.49	3.41	3.37	3.26	3.15
48.0	3.62	3.62	3.62	3.53	3.43	3.33	3.23	3.21	3.21	3.21
47.5	3.62	3.62	3.53	3.52	3.52	3.44	3.41	3.41	3.41	3.27
46.9	3.41	3.61	3.62	3.62	3.62	3.55	3.45	3.41	3.35	3.25
49.5	3.21	3.00	3.10	3.00	2.90	2.99	3.20	3.01	2.62	2.21
47.0	3.00	3.09	3.20	3.21	3.05	3.00	3.00	2.94	2.90	2.85
47.4	3.00	3.39	3.13	3.02	3.08	3.03	2.86	2.92	2.76	2.48
46.0	3.00	3.19	3.12	3.18	3.07	3.00	3.11	3.12	2.96	2.82
47.0	3.21	3.30	3.31	3.23	3.29	3.09	2.94	2.84	2.74	2.64
44.5	3.41	3.13	3.02	3.00	2.94	2.95	3.00	2.91	2.57	2.38
51.1	3.10	3.10	3.10	3.10	3.09	3.00	3.00	2.99	2.88	2.77
48.5	2.79	2.99	2.80	2.98	2.82	2.71	2.61	2.43	2.30	2.20
49.0	3.21	3.10	3.10	2.91	2.90	2.80	2.79	2.70	2.69	2.61
48.5	3.00	2.99	2.89	2.80	2.97	2.82	2.71	2.69	2.61	2.50
49.5	3.10	3.00	3.00	3.00	3.00	3.00	3.00	2.91	2.61	2.49
47.2	3.21	3.11	3.01	2.92	2.82	2.72	2.63	2.59	2.59	2.33
48.0	3.21	3.21	3.11	2.83	2.97	3.00	3.00	3.00	2.72	2.32
48.9	3.00	2.79	2.90	2.90	2.90	2.80	2.52	2.40	2.38	2.30
47.4	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.94	2.84
45.4	2.79	2.79	2.88	2.90	2.96	2.94	2.94	2.88	2.66	2.07
44.9	3.00	3.00	3.00	3.00	3.00	2.95	2.83	2.81	2.57	2.47
49.0	3.00	3.00	3.00	3.00	3.00	2.91	2.90	2.81	2.62	2.42
48.1	3.31	3.21	3.21	3.02	2.81	2.71	2.09	2.62	2.59	2.52
49.1	3.10	3.00	2.90	2.90	2.80	2.70	3.60	2.49	2.39	2.30
45.5	3.00	3.01	3.08	2.93	2.83	2.79	2.74	2.65	2.59	2.51
48.0	3.10	3.10	3.01	2.91	2.90	2.81	2.79	2.72	2.62	2.46
44.5	3.31	3.31	3.23	3.14	3.04	2.96	2.00	2.90	2.89	2.79
47.1	3.21	3.21	3.21	3.04	3.08	3.03	2.94	2.84	2.68	2.34
46.1	3.31	3.40	3.24	3.13	3.10	3.10	3.10	3.02	2.82	2.66
45.4	3.41	3.51	3.35	3.24	3.14	3.10	3.06	2.97	2.87	2.77
46.5	3.41	3.41	3.24	3.29	3.24	3.21	3.15	3.05	2.96	2.85
45.2	3.41	3.41	3.50	3.37	3.31	3.31	3.27	3.21	3.19	3.09
45.5	3.62	3.53	3.60	3.55	3.39	3.26	3.26	3.27	3.18	3.05
49.7	3.62	3.72	3.41	3.41	3.41	3.31	3.21	3.10	3.00	2.91
46.1	3.72	3.72	3.55	3.52	3.32	3.21	3.10	3.00	2.93	2.75
Means=53.65	3.989	4.002	3.976	3.941	3.902	3.318	3.735	3.631	3.484	3.269

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 18.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
67.0	7.22	7.47	7.46	7.45	7.64	7.62	7.27	7.29	6.90	7.42
65.0	6.93	7.16	7.30	7.49	6.90	6.64	6.48	6.34	6.14	5.83
67.5	7.62	7.17	6.90	7.23	6.60	6.50	6.69	6.62	6.24	5.85
64.0	6.93	6.93	6.93	6.93	6.91	6.70	6.62	6.47	6.32	6.23
63.1	7.04	6.70	6.70	6.70	7.12	6.31	6.06	6.33	6.08	5.65
60.5	5.77	5.77	5.68	5.54	5.54	5.54	5.48	5.18	4.93	5.25
61.0	5.77	5.54	5.64	5.62	5.33	4.84	4.73	4.80	4.67	4.38
58.1	5.77	5.10	5.16	4.85	5.15	5.31	4.86	4.82	4.54	4.38
56.0	5.31	5.05	4.85	4.76	4.73	4.77	4.64	4.81	4.85	4.14
52.0	4.85	4.95	4.58	4.40	4.47	4.33	4.20	4.25	3.84	3.65
49.2	4.96	5.08	5.31	5.10	5.30	5.70	4.97	4.86	4.64	4.52
45.5	5.19	5.08	5.08	4.91	5.14	5.18	4.98	4.76	4.58	4.48
44.0	4.61	4.61	4.43	4.38	4.16	4.23	4.32	4.15	4.14	3.94
40.0	3.69	3.69	3.06	3.95	3.78	4.15	3.79	3.69	3.61	3.42
40.9	3.57	3.31	3.08	2.99	3.06	3.22	3.02	2.92	2.82	2.72
39.9	3.92	4.02	3.83	3.73	3.82	3.69	3.87	3.79	3.60	3.39
41.0	3.92	3.92	3.92	3.87	3.83	3.89	3.71	3.52	3.39	3.27
40.6	3.69	3.88	3.85	3.85	3.86	3.66	3.29	3.23	3.11	2.92
40.4	3.92	3.82	3.80	3.74	3.69	3.70	3.98	3.60	3.30	3.21
39.6	3.69	3.69	3.69	3.64	3.55	3.46	3.37	3.34	3.22	2.95
40.0	3.46	3.46	3.46	3.41	3.34	3.34	3.06	2.99	2.90	2.71
42.9	3.62	3.44	3.33	3.37	3.41	3.29	2.97	2.79	2.70	2.62
44.0	3.41	3.32	3.31	3.25	3.10	2.92	2.79	2.76	2.58	2.40
43.0	3.41	3.41	3.34	3.31	3.27	3.15	3.00	3.00	2.91	2.82
39.9	3.21	3.21	3.21	3.17	3.08	3.00	2.76	2.69	2.65	2.57
40.8	3.00	3.00	2.94	2.85	2.76	2.70	3.78	2.65	2.53	2.44
39.5	3.21	3.05	3.00	2.92	2.74	2.50	2.48	2.32	2.22	2.06
36.1	2.90	2.90	2.85	2.79	2.79	2.54	2.38	2.38	2.38	2.21
37.9	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.46	2.18	2.34
37.5	3.21	3.05	2.90	2.79	2.79	2.64	2.54	2.48	2.48	2.41
36.5	2.90	2.90	2.85	2.79	2.79	2.72	2.65	2.58	2.50	2.42
34.0	3.10	3.03	2.89	2.69	2.69	2.65	2.57	2.43	2.34	2.27
31.2	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.72	2.59	2.59
33.0	2.59	2.72	2.79	2.79	2.79	2.70	2.40	2.55	2.41	2.00
37.0	2.79	2.95	2.90	2.79	2.79	2.72	2.65	2.59	2.59	2.41
38.5	2.69	2.93	2.95	2.80	2.58	2.50	2.42	2.38	2.36	2.29
35.1	2.79	2.79	2.79	2.79	2.79	2.74	2.67	2.60	2.59	2.50
35.9	3.00	3.00	2.91	2.79	2.79	2.79	2.73	2.59	2.59	2.49
34.5	2.79	2.65	2.50	2.40	2.62	2.55	2.38	2.38	2.22	2.01
34.5	2.59	2.59	2.55	2.47	2.40	2.38	2.37	2.30	2.22	2.15
32.1	3.00	2.73	2.59	2.59	2.53	2.46	2.40	2.38	2.37	2.31
34.0	2.69	2.69	2.65	2.59	2.59	2.55	2.47	2.40	2.34	2.27
34.0	2.90	2.83	2.79	2.78	2.65	2.55	2.46	2.33	2.14	1.92
33.0	2.79	2.79	2.79	2.79	2.66	2.53	2.39	2.32	2.25	2.18
32.0	3.00	3.00	3.00	3.00	2.88	2.75	2.62	2.54	2.47	2.36
35.0	2.90	2.90	2.82	2.68	2.61	2.54	2.46	2.39	2.25	2.11
33.1	3.21	3.07	3.00	3.00	3.00	2.90	2.70	2.63	2.53	2.39
32.1	3.10	3.04	2.94	2.81	2.79	2.75	2.62	2.54	2.45	2.28
33.2	3.21	3.21	3.14	3.00	2.86	2.79	2.79	2.73	2.66	2.59
34.5	3.31	3.23	3.13	2.98	2.84	2.71	2.58	2.50	2.33	2.10
33.8	3.00	3.00	3.00	3.00	2.85	2.71	2.58	2.51	2.40	2.26
33.0	3.31	3.38	3.38	3.23	3.21	3.12	2.91	2.71	2.56	2.49
34.1	3.41	3.34	3.27	3.20	3.06	2.91	2.78	2.71	2.65	2.58
33.2	3.41	3.41	3.38	3.31	3.24	3.17	3.10	3.04	2.93	2.79
34.5	3.52	3.44	3.37	3.30	3.15	3.10	3.07	2.93	2.84	2.77
35.0	3.62	3.55	3.48	3.39	3.04	3.11	2.98	2.91	2.83	2.74
34.0	3.62	3.46	3.41	3.39	3.27	3.08	2.87	2.66	2.59	2.50
Means=41.36	3.832	3.786	3.739	3.689	3.628	3.540	3.424	3.345	3.210	3.088

Velocities in feet per second at each tenth of depth, &c.—**Continued.**

STATION 20.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
53.9	5.89	6.44	6.95	7.20	6.91	6.92	6.97	6.40	5.67	5.69
52.0	6.29	6.47	6.54	6.79	7.07	7.20	7.27	6.99	6.70	6.36
53.0	6.35	6.58	6.63	7.00	7.22	7.03	6.88	6.77	6.64	6.52
52.8	6.47	6.58	6.65	6.75	6.47	6.41	6.37	6.54	6.42	6.29
53.0	6.47	6.47	6.47	6.44	6.22	6.07	6.19	6.03	5.77	5.77
54.5	6.47	6.[illegible]3	6.21	6.11	6.02	5.97	6.07	6.23	6.04	5.81
49.5	6.47	6.47	6.24	6.23	6.45	6.24	6.45	6.25	6.23	6.02
48.5	5.77	6.23	6.02	6.64	6.30	6.63	6.33	6.23	6.05	5.82
45.0	5.08	5.50	5.36	5.39	5.63	5.31	4.85	4.85	4.85	4.85
45.0	5.31	5.20	4.92	5.09	5.33	5.13	5.03	5.28	5.00	4.55
45.0	4.85	4.95	4.88	4.53	4.52	4.61	4.61	4.54	4.34	4.13
36.0	4.85	4.85	4.75	4.56	4.42	4.25	4.07	3.90	3.74	3.58
36.0	4.38	4.38	4.27	4.17	4.25	4.20	4.15	4.14	3.97	3.92
38.9	4.38	4.56	4.61	4.50	4.26	4.17	4.08	4.04	4.01	3.92
35.1	4.61	4.61	4.57	4.49	4.40	4.32	4.22	4.06	4.11	4.11
29.0	3.46	3.46	3.42	3.30	3.18	3.12	3.05	2.97	2.84	2.72
28.0	3.92	3.85	3.76	3.57	3.43	3.36	3.38	3.45	3.08	2.96
29.0	3.46	3.60	3.69	3.69	3.61	3.48	3.46	3.46	3.46	3.40
28.0	3.80	3.74	3.69	3.69	3.66	3.59	3.53	3.47	3.29	3.10
26.2	3.69	3.69	3.69	3.69	3.67	3.55	3.44	3.38	3.26	3.03
26.2	3.34	3.34	3.34	3.28	3.18	2.94	2.76	2.69	2.63	2.56
28.5	3.52	3.38	3.29	3.23	3.15	3.03	2.83	2.60	2.35	2.10
28.0	3.31	3.31	3.28	3.17	3.05	2.94	2.86	2.80	2.74	2.69
26.0	3.00	3.00	2.99	2.88	2.78	2.73	2.68	2.63	2.56	2.47
24.3	3.21	3.11	3.01	2.90	2.80	2.79	2.79	2.71	2.60	2.49
23.9	2.59	2.59	2.59	2.50	2.40	2.34	2.29	2.17	2.02	1.86
23.8	2.59	2.59	2.59	2.59	2.59	2.51	2.41	2.31	2.21	2.11
24.0	2.48	2.43	2.38	2.42	2.41	2.44	2.39	2.38	2.38	2.30
23.1	2.59	2.54	2.49	2.44	2.40	2.38	2.38	2.36	2.31	2.26
23.0	2.69	2.59	2.50	2.44	2.40	2.32	2.22	2.15	2.10	2.06
21.0	2.38	2.38	2.38	2.33	2.24	2.15	2.06	1.97	1.84	1.70
20.5	2.59	2.59	2.59	2.59	2.59	2.57	2.45	2.32	2.23	2.15
22.0	2.79	2.70	2.61	2.55	2.51	2.46	2.42	2.36	2.27	2.16
23.1	2.59	2.64	2.68	2.57	2.43	2.28	2.13	2.04	1.99	1.94
22.8	2.38	2.43	2.47	2.44	2.40	2.26	2.07	1.92	1.83	1.74
21.9	2.59	2.50	2.41	2.81	2.22	2.17	2.17	2.16	2.12	2.08
22.5	2.38	2.33	2.29	2.21	2.11	2.04	1.99	1.89	1.71	1.53
24.5	2.48	2.53	2.59	2.49	2.39	2.29	2.18	2.17	2.17	2.08
22.9	2.28	2.37	2.46	2.44	2.40	2.26	2.07	1.90	1.75	1.61
20.4	2.38	2.38	2.38	2.33	2.25	2.16	2.08	1.09	1.92	1.85
20.6	2.38	2.38	2.38	2.33	2.24	2.17	2.17	2.17	2.12	2.05
19.9	2.59	2.55	2.50	2.40	2.24	2.07	1.95	1.83	1.71	1.60
20.0	2.59	2.59	2.59	2.55	2.46	2.38	2.21	2.04	1.89	1.76
20.2	2.48	2.48	2.48	2.46	2.42	2.38	2.34	2.30	2.24	2.16
20.5	2.48	2.44	2.40	2.33	2.25	2.16	2.12	2.08	1.98	1.67
19.2	2.59	2.59	2.59	2.56	2.48	2.40	2.35	2.31	2.27	2.28
20.8	2.48	2.48	2.48	2.46	2.41	2.36	2.23	2.10	1.98	1.92
19.8	2.69	2.65	2.61	2.57	2.53	2.50	2.44	2.40	2.35	2.29
22.5	2.79	2.70	2.61	2.55	2.50	2.43	2.34	2.25	2.15	2.06
21.1	3.00	2.91	2.82	2.76	2.72	2.60	2.53	2.39	2.34	2.30
20.1	3.00	2.92	2.83	2.77	2.73	2.67	2.60	2.52	2.45	2.40
20.8	3.00	2.91	2.83	2.77	2.72	2.67	2.59	2.50	2.43	2.36
20.3	3.31	3.35	3.39	3.37	3.29	3.20	3.03	2.86	2.71	2.57
22.5	3.52	3.43	3.33	3.27	3.23	3.18	3.19	2.87	2.79	2.71
21.5	3.62	3.57	3.53	3.48	3.44	3.35	3.21	3.10	3.02	2.98
22.0	3.41	3.37	3.32	3.28	3.23	3.15	3.01	2.88	2.74	2.60
Means = 29.83	3.608	3.623	3.595	3.569	3.511	3.435	3.356	3.268	3.149	3.034

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 22.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	8	.9
44.0	5.42	5.88	6.08	6.65	6.78	6.57	6.39	6.16	6.05	5.91
45.0	6.23	6.19	6.11	6.03	5.93	5.89	5.89	5.92	5.88	5.57
45.5	6.12	5.92	6.07	6.55	6.99	7.03	6.83	6.61	6.41	6.20
45.5	6.00	6.52	6.68	6.88	6.93	6.67	6.36	6.14	5.94	5.70
43.8	6.00	6.29	6.26	6.32	6.17	6.00	5.93	5.79	5.89	5.00
45.5	6.00	6.32	6.16	6.21	6.27	5.89	5.92	5.88	5.68	5.42
46.0	6.23	6.13	5.98	5.71	5.88	6.00	5.93	5.87	5.72	5.61
42.5	6.23	6.23	6.23	6.30	6.35	6.38	6.47	6.47	6.44	6.17
42.5	5.77	6.06	6.04	5.87	5.77	5.72	5.63	6.20	5.86	5.77
42.5	5.77	5.77	5.25	5.60	6.28	6.72	6.69	5.93	5.79	5.77
42.0	5.54	5.92	5.83	5.65	5.46	5.28	5.18	4.68	4.28	4.40
40.0	4.38	5.11	5.17	5.08	4.91	4.15	4.33	4.38	4.58	4.90
38.1	5.08	5.61	5.53	5.23	5.07	4.90	4.72	4.53	4.35	4.17
35.8	4.85	4.85	4.65	4.38	4.38	4.32	4.45	4.85	4.17	3.60
35.8	4.38	4.46	4.54	4.43	4.20	4.28	4.24	3.92	3.83	3.75
30.0	4.61	4.47	4.38	4.38	4.07	3.69	3.55	3.43	3.37	3.30
29.9	4.61	4.61	4.55	4.43	4.33	4.27	4.33	4.34	4.20	4.05
30.0	4.15	4.22	4.27	4.27	4.18	4.04	3.97	3.90	3.80	3.75
29.5	4.27	4.33	4.38	4.38	4.30	4.16	4.03	3.90	3.83	3.76
29.0	4.38	4.64	4.78	4.51	4.30	4.17	3.99	3.78	3.58	3.40
21.0	2.99	3.09	3.19	3.17	3.07	2.97	2.87	2.77	2.66	2.55
21.0	3.69	3.69	3.69	3.60	3.45	3.30	3.16	3.01	2.85	2.69
21.5	3.46	3.36	3.26	3.23	3.23	3.19	3.09	2.99	2.82	2.66
20.8	3.69	3.59	3.50	3.43	3.38	3.31	3.17	3.02	2.63	2.70
21.1	3.34	3.29	3.25	3.20	3.15	3.08	2.99	2.89	2.80	2.72
20.1	3.23	3.27	3.32	3.29	3.20	3.11	3.06	3.01	2.87	2.40
20.0	2.88	2.88	2.88	2.86	2.81	2.76	2.72	2.67	2.61	2.53
19.5	3.23	3.14	3.04	2.90	2.90	2.90	2.91	2.82	2.74	2.67
19.0	2.88	2.83	2.79	2.76	2.76	2.76	2.70	2.61	2.51	2.28
23.5	3.62	3.52	3.42	3.33	3.23	3.10	2.96	2.81	2.66	2.52
22.2	3.21	3.21	3.21	3.21	3.21	3.09	2.86	2.65	2.40	2.17
20.9	2.79	2.79	2.79	2.79	2.79	2.78	2.74	2.70	2.63	2.56
17.2	2.90	2.90	2.90	2.79	2.75	2.72	2.67	2.56	2.46	2.35
18.1	3.21	3.05	2.92	2.76	2.65	2.54	2.42	2.30	2.19	2.10
17.0	2.38	2.31	2.24	2.17	2.09	2.02	1.94	1.80	1.66	1.53
16.2	2.17	2.17	2.17	2.17	2.05	1.92	1.78	1.62	1.45	1.28
15.0	1.96	2.06	2.15	2.25	2.26	2.23	2.19	2.12	1.96	1.80
15.2	1.96	2.06	2.09	2.15	2.10	2.01	1.91	1.83	1.75	1.68
14.5	1.86	1.86	1.86	1.86	1.84	1.81	1.79	1.75	1.67	1.59
16.9	1.96	1.96	1.96	1.96	1.89	1.82	1.75	1.66	1.57	1.49
15.5	2.07	2.10	2.13	2.16	2.12	2.05	1.99	1.93	1.88	1.83
16.0	2.38	2.31	2.25	2.18	2.06	1.92	1.79	1.59	1.37	1.14
17.4	2.17	2.17	2.17	2.16	2.05	1.94	1.85	1.82	1.78	1.75
17.1	2.17	2.21	2.25	2.27	2.16	2.05	1.95	1.92	1.91	1.85
15.9	2.17	2.17	2.17	2.17	2.14	2.11	2.08	2.01	1.92	1.72
16.5	1.96	1.96	1.96	1.96	1.93	1.89	1.86	1.75	1.64	1.52
15.5	2.17	2.17	2.17	2.17	2.15	2.11	2.08	1.98	1.84	1.66
17.1	2.07	2.03	1.99	1.95	1.89	1.82	1.74	1.59	1.45	1.31
15.1	1.96	1.96	1.96	1.96	1.92	1.86	1.80	1.70	1.54	1.38
14.8	1.86	1.89	1.92	1.95	1.92	1.86	1.80	1.74	1.66	1.58
15.1	1.76	1.76	1.76	1.76	1.68	1.55	1.42	1.30	1.18	1.10
15.3	1.96	1.96	1.96	1.96	1.94	1.91	1.88	1.82	1.75	1.65
15.5	2.28	2.25	2.21	2.18	2.15	2.11	2.08	2.04	1.98	1.92
15.2	2.38	2.32	2.25	2.19	2.12	2.06	2.00	1.94	1.89	1.80
15.0	1.76	1.79	1.82	1.85	1.84	1.81	1.78	1.74	1.69	1.63
15.2	1.86	1.83	1.80	1.77	1.74	1.70	1.67	1.63	1.58	1.53
16.1	2.17	2.14	2.11	2.07	2.04	2.00	1.97	1.87	1.77	1.66
16.1	2.07	2.03	2.00	1.96	1.93	1.90	1.87	1.86	1.86	1.70
16.2	2.38	2.38	2.38	2.38	2.25	2.12	1.98	1.86	1.76	1.65
16.1	2.38	2.38	2.38	2.38	2.35	2.32	2.29	2.21	2.13	2.04
15.8	2.59	2.56	2.52	2.49	2.43	2.36	2.30	2.25	2.21	2.16
16.4	2.69	2.62	2.55	2.48	2.45	2.42	2.38	2.30	2.25	2.13
16.8	2.90	2.83	2.76	2.69	2.66	2.62	2.59	2.52	2.45	2.37
17.0	2.90	2.86	2.83	2.79	2.75	2.72	2.68	2.61	2.54	2.47
18.8	2.69	2.65	2.61	2.58	2.53	2.49	2.45	2.42	2.38	2.34
Means = 24.08	3.372	3.414	3.301	3.374	3.333	3.251	3.181	3.087	2.937	2.836

Velocities in feet per second at each tenth of depth, &c.—**Continued.**

STATION 24.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
37.2	4.79	5.09	5.30	5.30	5.43	5.35	5.45	5.29	4.82	3.55
39.6	5.60	5.67	5.77	5.93	5.96	5.95	5.91	5.83	5.68	5.54
37.5	5.68	5.57	5.61	5.67	5.72	5.76	5.77	5.68	5.42	5.00
36.5	5.31	5.38	5.42	5.47	5.63	5.66	5.62	5.53	5.43	5.35
37.0	5.31	5.55	5.61	5.59	5.72	5.75	5.57	5.35	5.57	5.11
37.8	5.72	5.67	5.71	5.81	5.88	5.63	5.45	5.17	4.72	4.45
37.0	5.36	5.40	5.28	[illegible]	5.19	5.19	5.14	5.06	4.97	4.88
35.3	6.00	6.00	5.82	5.55	5.64	5.72	5.72	5.56	5.40	5.20
36.0	5.31	5.47	5.54	[illegible]	5.82	5.79	5.70	5.54	5.36	5.08
37.0	4.98	4.96	5.12	[illegible]	4.87	4.53	4.27	4.12	3.93	3.92
31.5	4.15	4.57	4.67	[illegible]	4.40	4.51	4.07	4.02	4.16	3.70
30.0	4.85	4.85	4.85	4.85	4.74	4.61	4.47	4.28	4.02	3.78
28.4	4.61	4.47	4.38	[illegible]	4.31	4.28	4.12	3.93	3.66	3.40
22.0	4.58	4.43	4.28	4.23	4.18	4.13	4.08	4.03	3.98	3.92
22.9	4.27	4.32	4.37	4.38	4.28	4.28	4.13	4.02	3.96	3.91
22.0	4.14	4.04	4.04	4.00	3.95	3.88	3.84	3.77	3.63	3.47
20.0	3.46	3.46	3.46	3.44	3.38	3.34	3.25	3.15	3.03	2.88
13.8	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.00
14.0	2.30	2.30	2.30	2.30	2.26	2.16	2.06	1.96	1.88	1.80
14.8	2.53	2.53	2.53	2.53	2.49	2.42	2.35	2.28	2.19	2.10
14.5	2.30	2.30	2.30	2.30	2.34	2.40	2.47	2.50	2.16	1.83
14.0	2.30	2.30	2.30	2.30	2.27	2.21	2.14	2.08	1.93	1.77
13.1	2.18	2.18	2.18	2.18	2.17	2.15	2.12	2.19	2.06	2.03
12.2	2.07	2.10	2.12	2.15	2.18	2.13	2.07	2.12	1.86	1.90
12.2	2.18	2.15	2.13	2.10	2.07	2.04	2.01	1.99	1.96	1.93
12.2	2.53	2.50	2.47	2.44	2.42	2.33	2.20	2.09	1.97	1.80
14.9	2.59	2.59	2.59	2.59	2.49	2.34	2.18	2.02	1.87	1.71
14.6	2.38	2.38	2.38	2.38	2.33	2.24	2.15	2.06	1.98	1.90
13.5	1.96	1.96	1.96	1.96	1.94	1.85	1.77	1.68	1.60	1.52
12.1	1.86	1.84	1.81	1.79	1.76	1.74	1.71	1.68	1.66	1.63
10.2	1.76	1.72	1.67	1.63	1.59	1.55	1.51	1.48	1.44	1.41
9.5	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.04	0.94
8.9	1.24	1.19	1.15	1.10	1.05	1.03	1.03	1.03	1.00	0.90
8.4	1.55	1.51	1.47	1.41	1.38	1.32	1.24	1.15	1.07	0.98
9.0	1.76	1.67	1.57	1.48	1.38	1.31	1.25	1.25	1.13	1.06
9.3	1.34	1.29	1.25	1.20	1.15	1.10	1.05	0.98	0.89	0.79
8.0	1.34	1.30	1.26	1.22	1.18	1.14	1.10	1.05	1.01	0.96
10.1	1.45	1.41	1.37	1.32	1.28	1.24	1.19	1.14	1.09	1.04
10.1	1.45	1.43	1.41	1.38	1.36	1.34	1.29	1.24	1.19	1.14
10.2	1.34	1.30	1.26	1.22	1.18	1.15	1.20	1.21	1.18	1.13
10.1	1.34	1.32	1.30	1.28	1.26	1.24	1.19	1.14	1.09	1.04
10.1	1.34	1.34	1.34	1.34	1.34	1.34	1.29	1.24	1.19	1.14
10.0	1.34	1.32	1.30	1.28	1.26	1.24	1.19	1.14	1.09	0.99
9.5	1.34	1.32	1.29	1.27	1.25	1.16	1.06	0.96	0.83	0.67
9.0	1.34	1.29	1.25	1.20	1.16	1.11	1.07	0.91	0.87	0.82
9.0	1.24	1.20	1.16	1.13	1.09	1.05	1.01	0.96	0.92	0.97
8.5	1.24	1.20	1.17	1.13	1.20	1.06	1.01	0.84	0.67	0.53
9.5	1.45	1.42	1.40	1.37	1.35	1.26	1.24	1.24	1.20	1.15
10.5	1.55	1.53	1.50	1.47	1.43	1.34	1.34	1.34	1.34	1.34
11.2	1.96	1.98	2.10	2.03	2.05	2.04	1.97	1.87	1.76	1.60
11.8	2.28	2.23	2.18	2.13	2.08	2.03	1.98	1.93	1.88	1.84
12.0	2.07	2.07	2.07	2.07	2.07	2.05	2.02	2.00	1.97	1.93
Means = 17.88	2.840	2.816	2.812	2.787	2.771	2.729	2.663	2.587	2.483	2.335

STATION 26.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
23.2	3.75	3.82	3.85	4.00	4.15	4.20	4.18	4.08	3.88	3.60
22.5	3.54	3.61	3.65	3.62	3.53	3.48	3.46	3.40	3.27	3.14
23.5	3.80	4.14	4.45	4.45	4.40	4.37	4.35	4.22	4.02	3.80
23.5	3.98	4.10	4.18	4.26	4.33	4.22	4.10	4.10	4.17	4.10
24.8	4.04	4.16	4.27	4.38	4.30	4.22	3.93	3.78	3.64	3.50
23.8	4.15	4.34	4.48	4.47	4.45	4.50	4.45	4.38	4.29	4.15
24.9	3.98	4.13	4.26	3.99	3.69	3.93	4.15	3.94	3.70	3.40
23.2	4.04	4.09	4.14	4.15	4.15	4.15	4.15	4.04	3.83	3.61
22.4	4.15	4.15	4.15	4.11	4.04	4.01	3.96	3.90	3.85	3.86
22.5	3.92	3.92	3.92	3.83	3.73	3.63	3.53	3.43	3.33	3.23
22.0	3.80	3.80	3.80	3.91	4.07	4.06	3.86	3.67	3.57	3.47
18.5	3.92	3.92	3.92	3.90	3.90	3.90	3.82	3.65	3.48	3.31
17.5	3.46	3.46	3.46	3.45	3.42	3.38	3.34	3.31	3.26	3.20
16.0	2.99	2.99	2.99	2.99	3.09	3.20	3.37	3.20	3.02	2.83
15.0	2.99	2.99	2.99	2.99	2.90	2.99	2.99	2.99	2.99	2.99
9.9	3.46	3.46	3.46	3.46	3.23	3.00	2.78	2.54	2.38	2.00
8.9	2.30	2.30	2.30	2.30	2.30	2.27	2.22	2.17	2.12	2.06
8.8	2.07	2.07	2.07	2.03	1.98	1.93	1.88	1.83	2.78	2.73
Means = 19.49	3.574	3.636	3.686	3.683	3.634	3.636	3.584	3.479	3.421	3.273

Velocities in feet per second at each tenth of depth, &c.—Continued.

MEAN VALUES OF STATION MEANS.

f station.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9
2	3.441	3.450	3.457	3.407	3.346	3.283	3.239	3.217	3.127	2.969
4	2.716	2.733	2.729	2.698	2.668	2.571	2.495	2.423	2.339	2.243
6	3.112	3.136	3.103	3.091	3.090	2.991	2.908	2.816	2.677	2.527
8	3.438	3.435	3.434	3.454	3.405	3.336	3.246	3.160	3.041	2.917
10	3.622	3.657	3.696	3.719	3.675	3.649	3.525	3.448	3.310	3.079
12	3.767	3.768	3.727	3.708	3.675	3.600	3.544	3.447	3.300	3.152
14	3.917	3.894	3.846	3.820	3.820	3.749	3.656	3.545	3.405	3.255
16	3.989	4.002	3.976	3.941	3.902	3.818	3.735	3.631	3.484	3.269
18	3.832	3.786	3.739	3.681	3.628	3.540	3.424	3.345	3.210	3.088
20	3.608	3.623	3.595	3.569	3.511	3.435	3.356	3.268	3.149	3.034
22	3.372	3.414	3.391	3.374	3.333	3.251	3.181	3.087	2.937	2.836
24	2.810	2.816	2.812	2.787	2.771	2.729	2.663	2.587	2.483	2.335
26	3.574	3.636	3.686	3.683	3.664	3.636	3.584	3.479	3.421	3.273
Means =	3.477	3.488	3.476	3.456	3.422	3.353	3.274	3.189	3.068	2.921

MEAN VALUES OF ALL OBSERVATIONS.

Means =	3.466	3.475	3.458	3.439	3.405	3.332	3.249	3.161	3.034	2.890

5.—Red River Landing, Louisiana.

Office Mississippi River Commission,
Saint Louis, Mo., August 15, 1884.

: I have the honor to submit a report on experimental work performed at Red · Landing and vicinity, by Assistant John Ewens, in the season 1881-'82.

e work embraced the following particulars: Determination of velocities in ver- planes; bend soundings and transverse velocity observations; experiments with urrent meter.

tical velocities.—These observations were made during the period from July 12 to mber 18, 1882, at stages ranging from 41 feet on the gauge, 8 feet below the high r of the year, down to 9 feet, the low water of the year. They are thirty-five in er, thirty-two of which were on the Mississippi section, distributed irregularly g thirteen of the fourteen velocity stations permanently located on the section. emaining three were taken at one station on the Atchafalaya section.

e meter (Ellis, Nos. 5 and 7) was used throughout, and was run for one minute at foot in depth descending; the series was not repeated in ascending.

e results are shown in detail on sheets Nos. 1-7, a plotted curve accompanying table of velocities.* For the purpose of computing the mean velocities in some where observations were wanting, values were interpolated, and in all cases the ble curve of velocity was continued to the surface and to the bottom; portions obtained are denoted by dotted lines.

ese curves were divided vertically into tenths, the velocities at the points so fixed tabulated by stations, and the mean for each station computed and plotted. e results a series of thirteen station means, of eleven terms each. All the obser- ns were then combined into a single vertical or grand mean. The station and l means are shown on pages 8 and 9.

will be observed that the surface velocity in most of these curves, and in the l mean, is distinctly lower than that at the first tenth. To determine the form e curve in this part, the first tenth of each curve was divided into fourths, and ean velocity at the three intermediate points computed, giving velocities at 1, d 3 fortieths of depth, in addition to the tenths already determined. The re- g curve is the dotted line 1, 2, 3, shown in the double-scale curve on sheet No. he form of this partial curve shows that the velocity is maintained nearer the ce than the main curve would imply, and leads to the suspicion that the ap- tly low surface velocity is the result of a constant error caused by running the r too near the surface. (See, however, Catamaran experiment.)

nputation of the elements of the mean curve from three points makes the ratio e semi-axis negative; the curve is therefore an ellipse, of which the axis (as- l parallel to the water-surface) lies at not more than one-thirtieth of the depth. nean velocity is at about six-tenths of the depth.

* Not published.

The form of the Atchafalaya curve, as far as the data give it, does not appear vary materially from that of the Mississippi, the maximum velocity being near surface, and the mean somewhat below mid-depth.

Bend soundings.—The section selected was at Brunette Point, 17 miles below Red River Landing. Soundings were made and velocities observed six times, from May 30 to October 31. The results are presented graphically on pages 10 and 11. The section of October 31 was not plotted since, in the absence of instruments, the soundings were located by comparison with those of a previous date, and therefore have no independent value; the velocities, however, being doubtless located with sufficient exactness, were plotted for the sake of extending the comparison.

The gauge-readings given in the notes on this section being from the Red River Landing gauge, the elevation of water surface above Cairo datum was obtained by comparison of Red River and Port Hickey gauges, the latter being corrected for September 29 and October 31, when it was evidently in error, by reference to the Baton Rouge gauge and comparison of readings at the corresponding stages in 1883.

The locus of maximum velocity lies in the convex side of the river, where a noticeable fill is shown by the section of September 29, as the velocity decreased.

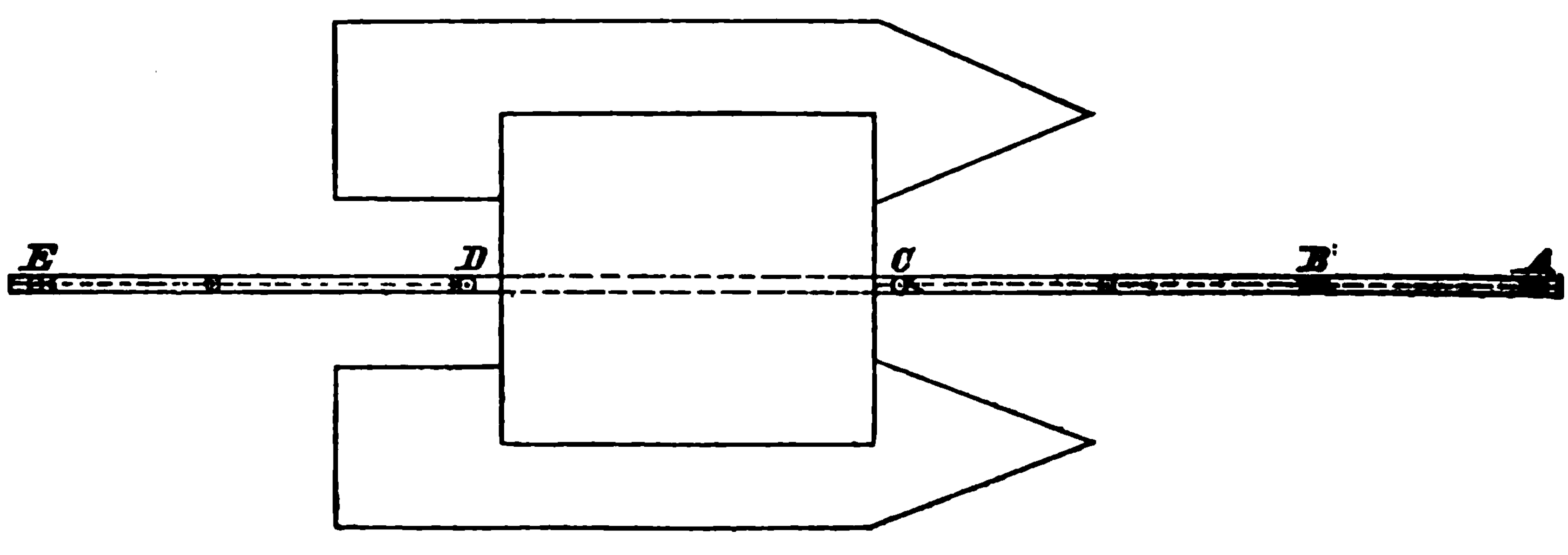
The velocities through this section were observed at depths varying from 3 to 35 feet, and for comparison have been reduced to mid-depth by using coefficients derived from the vertical curves at Carrollton, where the conditions are somewhat similar.

In order to compare the flow at this section with that at Red River Landing for the same dates the discharges were computed, with the following results:

Date.	Gauge at Red River Landing.	Brunette Bend.		Red River Landing.		Excess at Brunette Bend.	
		Mean velocity.	Discharge.	Mean velocity.	Discharge.	Cubic feet.	Per cent.
May 30	41.31	5.38	1,245,224	4.93	1,135,082	110,142	9.7
June 27	41.70	5.42	1,228,480	4.64	1,092,263	136,217	12.5
July 25	40.00	4.86	1,074,400	4.28	982,434	91,966	9.4
August 9	32.10	3.63	733,791	3.33	649,672	84,099	13.0
September 29	14.36	2.60	383,400	2.53	309,557	73,843	23.8

These differences seem to indicate that in sections of this character, where the main flow of the river sets across the convex and shoaler side of the bend, the mean velocity in the deeper part of the section cannot safely be assumed to be the same function of the mid-depth velocity as in straight reaches. Naturally the percentage of low-water excess follows the increased ratio of the volume below a given subsurface plane to the whole volume of the river.

In order to determine the effect of the catamaran skiffs on the current near the surface, a series of fourteen runs of sixty seconds each was made at the depth of 1½ feet at each of the points indicated in the following diagram, the results being given in the accompanying table:



REGISTRATION.

A.	B.	C.	D.	E.
25. 27	26. 25	24. 25	26. 26	25. 25
25. 25	27. 25	28. 26	27. 27	26. 26
25. 26	25. 26	25. 24	29. 27	27. 26
24. 26	27. 27	24. 27	25. 26	27. 27
25. 26	24. 25	26. 26	25. 25	24. 25
26. 25	26. 25	25. 26	25. 24	24. 25
27. 27	26. 26	27. 27	25. 27	26. 25
Mean = 25. 64	25. 64	25. 29	26. 00	25. 50

Assuming that the extent of the experiment (14 minutes) would eliminate errors arising from fluctuations of the current, the means of this table point to a small retardation between the skiffs forward and an acceleration aft. It is possible that the low surface velocity noticed in the vertical curves may be in some degree due to interference from this source, which would be more marked in approaching the surface.

Ellis meter No. 5 was rated once and No. 7 twice early in August. The rating of No. 7 of August 9 was used for all observations made with that instrument; the rating used for No. 5 was that taken at Saint Louis, Mo., November 10, 1881.

METER RATINGS.

[$y=ax+b$, in which y = velocity in feet per second; x=registrations per minute.]

Locality.	Date.	Meter.	Number of observations.	Registrations per revolution.	Course.	Constants. a.	Constants. b.	Authority.	Range of velocities.	Where taken.
					Feet.					
Saint Louis, Mo	1881. Nov. 10	Ellis No. 5	18	1	150	.06245	.148	J. Ewens.	1.17–9.49	Reservoir.
Red River Landing .	1882. Aug. 3	Ellis No. 5	12	1	150	.06350	.002	do	1.45–6.86	Lake.
Do	Aug. 4	Ellis No. 7	9	1	150	.06346	.045	do	2.78–9.16	Do.
Do.............	Aug. 9	Ellis No. 7	12	1	150	.06216	.177	do	1.56–7.35	Do.

Tracings of the locations of the various sections are appended.

Very respectfully, your obedient servant,

E. H. TWINING,
Assistant Engineer.

First Lieut. SMITH S. LEACH,
Corps of Engineers, U. S. A.,
Secretary Mississippi River Commission.

Velocities in feet per second at each tenth of depth as resulting from the velocity observations made at Red River Landing, La., in 1882.

STATION 1.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
24.0	2.13	2.75	2.77	2.73	2.68	2.45	2.68	2.69	2.51	[illegible]	2.19

STATION 2.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
61	2.80	3.21	3.21	3.14	3.17	3.05	[illegible]	3.08	[illegible]	3.02	2.29
24	2.40	2.50	2.54	2.52	2.30	2.46	2.25	2.21	2.16	1.88	1.50
Means = 42.5	2.60	2.86	2.88	2.83	2.74	2.76	2.56	2.64	2.56	2.45	1.90

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 3.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
30	2.52	2.71	2.65	2.71	2.77	2.65	2.52	2.71	2.46	2.40	2.00
31	2.33	2.84	2.96	2.82	2.84	2.87	2.90	2.52	2.55	2.64	2.00
Means = 30.5	2.42	2.78	[illegible]	2.76	[illegible]	2.76	2.71	2.62	2.50	2.33	2.00

STATION 4.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
40.0	4.15	4.06	4.08	3.90	3.84	3.52	3.53	3.58	3.32	3.21	2.70

STATION 5.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
39	2.84	3.07	3.14	2.90	3.07	2.84	2.65	2.29	1.98	1.97	[illegible]
35	2.77	3.02	3.02	2.96	2.84	2.74	2.46	2.28	1.90	1.52	[illegible]
34	2.65	2.75	2.80	2.76	2.70	2.40	2.31	1.94	1.65	1.27	[illegible]
34	2.46	3.01	2.92	2.90	2.80	2.71	2.44	2.86	2.01	1.68	[illegible]
23	2.54	2.87	2.91	2.94	2.65	2.78	2.76	2.80	2.60	2.51	[illegible]
24	2.47	2.88	2.93	2.78	2.88	2.70	2.78	2.78	2.45	2.29	[illegible]
25	2.54	2.91	2.91	2.90	2.91	2.80	2.78	2.52	2.41	2.13	[illegible]
Means = 30.4	2.61	2.97	2.97	2.89	2.86	2.71	2.60	2.41	2.14	1.91	[illegible]

STATION 6.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
41.0	3.02	3.02	2.96	2.95	2.89	2.65	2.60	2.58	2.30	2.11	[illegible]

STATION 7.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
35.0	2.84	2.78	2.65	2.63	2.53	2.42	2.33	2.13	[illegible]	1.67	[illegible]

STATION 8.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
33	2.02	2.21	2.29	2.21	2.15	2.08	1.83	1.90	1.60	1.46	[illegible]
23	1.92	2.18	2.30	2.22	2.23	2.16	2.13	2.04	1.96	1.94	[illegible]
Means = 28.0	1.97	2.20	2.30	2.22	2.19	2.12	1.98	1.97	1.78	1.70	[illegible]

STATION 9.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
45.0	3.20	3.38	3.30	3.15	3.14	3.02	2.90	2.88	2.78	2.42	[illegible]

STATION 11.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
60	3.02	2.77	2.51	2.51	2.68	2.65	2.25	2.13	2.01	1.61	[illegible]

STATION 12.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
50	[illegible]	3.67	3.77	3.67	3.61	3.54	3.45	3.31	3.21	2.77	[illegible]

STATION 13.

Depth.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
55	3.60	4.14	3.90	3.98	3.90	3.94	3.00	3.60	3.64	[illegible]	[illegible]
57	3.60	3.90	[illegible]	3.77	3.66	3.58	3.54	3.43	2.10	2.73	[illegible]
24	2.29	2.60	2.60	2.66	2.63	2.58	2.47	2.44	2.28	2.29	[illegible]
23	2.67	2.63	2.57	2.47	2.72	2.50	2.51	2.40	2.50	[illegible]	[illegible]
22	2.72	2.73	2.70	2.68	2.62	2.59	2.41	2.40	2.34	[illegible]	[illegible]
Means = 36.2	2.66	3.20	3.16	3.11	3.11	3.05	2.97	2.93	2.81	2.63	[illegible]

Velocities in feet per second at each tenth of depth, &c.—Continued.

STATION 14.

Depth.	Surface.	.1	.2	[redacted]	.4	.5	.6	.7	.8	[redacted]	Bottom.
44	2.71	4.06	4.05	4.02	3.93	3.83	3.63	3.63	3.46	3.35	3.15
34	2.89	3.30	3.14	3.14	3.27	3.14	3.00	2.90	2.82	2.10	2.00
25	2.84	2.75	2.71	2.72	2.59	2.55	2.40	2.05	2.02	1.81	1.20
18	1.52	1.65	1.66	1.61	1.59	1.58	1.52	1.50	1.46	1.02	0.90
16	1.61	1.85	1.84	1.74	1.80	1.79	1.60	1.60	1.50	1.48	1.10
17	1.86	1.94	1.88	1.78	1.87	1.74	1.61	1.60	1.48	1.31	1.00
17	2.18	2.12	2.08	2.04	2.00	1.92	1.79	1.73	1.70	1.66	1.30
Means = 24.6	2.57	2.52	2.46	2.43	2.43	2.36	2.25	2.12	2.06	1.82	1.52

MEANS OF ALL OBSERVATIONS.

....	2.65	2.88	2.87	2.81	2.80	2.70	2.59	2.50	2.35	2.15	1.74

ATCHAFALAYA SECTION.—STATION 5.

20	2.38	2.65	2.65	2.71	2.65	2.71	2.71	2.65	2.46	1.99	1.50
19	2.68	2.79	2.67	2.60	2.58	2.57	2.50	2.25	2.20	1.85	1.50
21	2.33	2.65	2.59	2.66	2.55	2.50	2.53	2.40	2.21	2.05	1.60
Means = 20.0	[redacted]	2.70	2.64	2.66	2.59	2.59	2.58	2.43	2.29	1.93	1.53

AREAS IN BRUNETTE BEND.

[redacted]	Gauge.	Width.	Area.	+ Scour. − Fill.	Datum area.
1882.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Sq. feet.*
May 30	61.6	2,729	230,918	......	230,918
June 27	61.9	2,751	226,640	− 4,552	226,365
July 25	60.4	2,704	220,980	− 2,115	224,251
August 9	53.2	2,553	202,870	+ 316	224,568
September 29	36.0	2,407	147,738	− 11,976	212,590
October 31	32.9	2,354	....	....	....

Means of velocities at each tenth of depth obtained from all the observations at the discharge sections in 1882, with number of observations and depth of mean velocity below the surface in parts of the whole depth.

Section.	Number of observations.	Depth of mean.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
Paducah	211	0.63	2.340	2.340	2.320	2.290	2.250	2.220	2.170	2.070	1.970	1.840	1.550
Columbus	101	0.71	2.665	3.077	3.178	3.205	3.227	3.204	3.126	2.968	2.818	2.519	2.106
Helena	90	0.61	5.157	5.145	5.042	4.916	4.812	4.709	4.493	4.288	3.982	3.577	2.999
Hays' Landing ..	620	0.60	3.468	3.475	3.458	3.439	3.405	3.332	3.249	3.161	3.034	2.690	*2.750
Red River Landing	33	0.61	2.650	2.880	2.870	2.810	2.800	2.700	2.590	2.500	2.350	2.150	1.740

* Interpolated.

MEAN OF ALL SECTIONS.

Depth of mean.	Surface.	.1	.2	.3	.4	.5	.6	.7	.8	.9	Bottom.
0.63	3.256	3.383	3.373	3.332	3.299	3.233	3.126	3.001	2.831	2.595	2.235

MEAN, EXCLUDING PADUCAH.

0.63	3.484	3.644	3.637	3.592	3.561	3.486	3.364	3.234	3.046	2.784	2.406

APPENDIX E.

REPORT OF CAPTAIN J. H. WILLARD, CORPS OF ENGINEERS, SECRETARY OF CONSTRUCTION COMMITTEE.

[The Mississippi River Commission, office of the Committee on Construction, 2653 Olive street, Saint Louis, Mo.]

SAINT LOUIS, MO., *October* 20, 1884.

SIR: In compliance with instructions from the president of the Commission, I have the honor to report the work of this office from November 1, 1883, the date of the last report, to September 30, 1884.

Captain Sears continued in charge until April 11, 1884, when he was transferred to the charge of the third district. By a resolution of the Commission November 20, 1883, his designation was changed from executive officer to secretary of the committee on construction; and in addition to the duties of that office he was made assistant to the committee as constructing officer for plant, and was charged with the purchase of such material and supplies as district officers could not conveniently obtain for themselves, and with the consolidation and publication of monthly reports.

The floating and other public property for which he was responsible, not required for the general service, and the public funds held by him for purchases on account of the works of improvement were transferred to the district officers, and the responsibility was laid upon them for obtaining all supplies and material necessary for the proper conduct of their works, either by direct purchase or through the purchasing officer by timely requisition, as they might find most advantageous and convenient.

When called upon for such service, this office fills requisitions by methods suited to the exigencies of the case and delivers the supplies in the most expeditious way, due regard being paid to economy of time and money. The accounts when audited are transmitted with certified bills and bills of lading, with or without the department vouchers, as may be desired, and the district officer checks the invoices and makes the payments. This method appears to give general satisfaction and is well adapted to the system of conducting the work. The accounts are simplified, and disbursing officers, having accurate knowledge at all times of the actual state of their allotments, can gauge their operations with greater freedom and economy.

As district officers are expected to and generally do supply themselves with stores and material for the works under their charge, purchases made through this office are usually on small orders or for supplies that the exigencies of the work require beyond what may be fairly estimated, or for which the district officers cannot provide storage.

The so-called contract system finds its limitations here, and if insisted upon will seriously impede the work of improvement and add largely to its cost.

Requisitions are filled by inviting proposals by circular letters when time will permit, by purchase in open market or by bargaining with the same care for the interests of the Government that a good business man adopts for the protection of his own. These methods are generally required by the exigencies of the service and are sanctioned by law.

The districts above Cairo were included in the general work under the Commission by the act approved July 5, 1884. Being more happily situated with respect to climate and obtaining with little difficulty labor, supplies, and stone for works conducted on a smaller scale than in the lower river, they do not require the assistance of this office and need not be considered in estimating for the general service.

The chief business of this office is now the management of the general service, consisting of steam tow-boats and barges, and the delivery of stone, wire, coal, and general supplies to the districts below Cairo.

Owing to the changes in the organization of the office which I have mentioned, separate statements are given of the expenditures under Captain Sears, as executive officer from November 1, 1883, to February 29, 1884, when the transfers were completed, and as secretary and assistant from March 1 to April 11, 1884, the date of his relief, and from April 12 to September 30, 1884, the period during which I have had charge. Under the present arrangement, the expenses of the general service are finally charged to the first, second, and third districts; those for plant, outfit, and repairs being divided equally, and the remainder, embracing administration, inspection, and running expenses of the steamboats, in proportion to the service rendered as computed from the mileage.

After the transfer of public property to the several districts, there were left for the general service, the inspection and tow-boat Mississippi, the tow-boat Minnetonka, bought April 10, 1884, after a thorough trial of three months under charter, fifty-six stone-barges, one store-boat, constructed out of an old hull, and one pumping-boat, the last two being kept at the coal-fleet at Cairo.

The plant has been kept in a high state of efficiency by prompt and liberal expenditures. The steamboats are in first-rate order, and are worth almost as much to the service as when first received.

The stone-barges are in fair condition, and are worth their cost to the Government; but from the nature of the service in which they are engaged, they would probably not fetch one-third of their first cost.

They have had hard usage in loading, in handling in rough water, and in long and unavoidable detentions at the works, both loaded and light. Constant attention has been required to keep them repaired, well calked, and seaworthy; and in addition to repairs made at docks and ship-yards, two men have been kept fully occupied at the fleet at Cairo, calking and repairing above light-water.

The plant at my disposal being inadequate to the needs of the districts, I made application for a large and powerful tow-boat for use on the Mississippi River for long trips, and for a small boat for service between the quarries and the fleet at Cairo. An urgent request was also made for increasing the number of stone-barges. The estimates received the approval of the Commission at its session, July 22, 1884, but owing to the comparatively small amount then available, the construction of the tow-boats was postponed; the increase of the barge-fleet was approved, however, and it was resolved to build thirty model barges at a cost not exceeding $150,000. Application was made to the Secretary of War for authority to buy or build under the resolution, and was approved August 16, 1884.

The appropriation for the Missouri River having become nearly exhausted early in the season, the plant required for that work was laid up at Bushberg. While on an inspection trip down the river, it occurred to me that it would be to the advantage of the Government to use the Missouri River stone-barges during the summer on the Mississippi improvement. After consultation with Major Suter, the officer of engineers in charge, authority was asked and obtained for temporary transfer of thirty barges to the general service, with permission to expend $2,400 in repairs.

By the wording of the act approved July 5, 1884, the Missouri River Commission cannot expend the new appropriation for that river until the plans shall have been approved by Congress, so that these barges are still at the disposal of the general service, and can be retained till navigation closes, or until called for, when they will be returned to the fleet at Bushberg, or will be cared for by the general service, as may be most convenient.

About $1,200 have been expended on them, and as they have been kept more than twice as long as was contemplated the amount for returning them in good order should be increased to $6,000.

The cost of chartering fifteen model barges equivalent in capacity to those borrowed would not have been less than $16,200 for the time they have been employed for the general service.

During the summer I inspected a great number of model barges, had lines and dimensions taken from those most approved, and collected specifications from well-known builders. After a study of the best models, I prepared specifications and had plans drawn which I submitted to experienced ship-builders for suggestions and improvement.

As the construction of new tow-boats was postponed, and the general service had the use of Missouri River barges, the necessity for the new barges was not so pressing; and as the amount of money required for the new barges was so great, and the necessity of having boats that will last for many years so plain, I thought it wise to delay construction until plans and specifications could be perfected. The drawings are now being revised on complete specifications, and it is thought that barges built according to the new designs will be the best wooden barges afloat in these waters. Under the circumstances, the delay in constructing them has been to the advantage of the Government; for had they been put in hand as soon as possible after authority was obtained, the greater number would have been finished only in time to cause expense for care during the winter. Time has also been given for comparing plans, and they can now be built without haste in season for work next spring.

The amount already allotted for their construction is considered ample.

The life of a wooden boat on the Mississippi is variously estimated at from six to nine years, the chief enemy being dry-rot. If an entirely new plant were to be constructed, I should recommend either iron or composite hulls as being the most economical in the long run.

But the amount already invested in plant, necessarily built in haste, because the work of improvement was imperatively demanded, is now so great that I do not feel justified in recommending those forms of construction except for steamboats. Should Congress, however, decide to set apart a large sum to be applied in allotments for a term of years for the improvement of the Mississippi, I think that there can be no question but that new plant should be constructed of iron, either wholly or in part, according to the service required.

I must now renew my earnest request for the two tow-boats, hulls to be of iron or composite construction.

Preliminary estimates have been made for them, and drawings projected; but construction should not be undertaken until plans and detailed estimates have been prepared.

For long trips, especially, a much more powerful boat than the Mississippi is required; indeed, I recommend a larger boat than the Minnetonka; and, in making the preliminary estimate, I have taken her for a model, adding $12,000 for the increase in size and construction of hull, and $8,000 for larger boilers and heavier machinery.

The towing service is attended with great risks, and as the Government does not insure, the danger should be reduced to a minimum by using boats with surplus power. The boats now in service can take down stream from twelve to eighteen loaded barges; but they cannot tow economically more than from eight to twelve empty barges up stream against a strong current without carrying more steam than allowed on their inspection papers.

One of the obstacles to the delivery of stone has been the difficulty experienced in supplying quarries with empty barges. By the use of a small boat of good power and light draft, about the size of the Missouri River Commission tow-boat Stone, to collect loaded barges at the fleet and to distribute empty barges to the quarries on both rivers, at least four days could be saved on nearly every trip of the large boats, and the service to the districts considerably increased and made much more regular.

The small boat could also take a fair sized tow of eight or ten loaded barges to the first district, and even to the second in an emergency, and could bring back five or six empty barges against an average current.

If built of iron, the large boat would cost about $60,000, and the small boat not much less than $30,000; the prices would be about 10 per cent. less, if built with composite hulls, and about 20 per cent. less if built with strong wooden hulls. On completion of the tow-boats, the Mississippi should be laid off as a spare boat for tours of inspection, temporary increase of the service, or to take the place of any of the others in case of accident, the crews being simply transferred. The costly and most unsatisfactory method of chartering would thus almost entirely be obviated. The Mississippi is naturally selected for reserve; she has not sufficient power to handle large tows in a strong current, not having been built solely for towing; and having an iron hull, she would not deteriorate while laid up.

In regard to the construction of new plant, I believe it would be to the best interests of the Government to follow the methods of business men and place the work on bids solicited only from builders of established reputation.

It is not only a question of construction, but of material. Wooden hulls should be entirely of the best oak, except decks and bulkheads; and as first class ship-timber has become very scarce, I think it safe to say that there are not more than half a dozen builders in the West who use or can control any considerable amount of the best upland oak. In a general competition, the lowest bidders are almost always parties with little capital, who have no facilities for building on a large scale, and who use the short-lived oak of lowland growth, which rots in two or three years. If iron or composite construction is adopted, the choice would be limited naturally to the few builders engaged in that kind of work.

With new tow-boats, new barges, and plant now on hand in good order, at least 20,000 cubic yards a month could be furnished regularly to the three districts below Cairo during active operations, large reserves being unloaded on the bank during spring high water.

The amount of stone furnished by the general service during the past year has been greater than in any year since the work was undertaken, but it has fallen short of requisitions from the districts, and the officers in charge have been somewhat embarrassed in their operations by uncertain and irregular delivery. That the progress of their work was not seriously delayed, was due in part to the fact that stone was delivered on the bank on early requisitions, but chiefly to long-continued high water, which prevented active operations till the season was well advanced.

Stone can be bought cheap only from quarries at least 50 miles above Cairo on the Mississippi or Ohio; if obtained from other sources, it must be transported to the river by rail at great expense for freight and handling.

All the stone furnished by the general service this season was bought in open market from a number of quarries on both rivers above Cairo, the greater part having been taken from the Southern Illinois Penitentiary at Chester.

It was of good quality and weight, and cost from 50 to 60 cents the cubic yard loaded on barges at the quarries, the price depending on the kind of stone furnished and the distance of the quarries from the river bank.

I have dealt generally directly with parties owning or controlling quarries, and the terms have been most favorable to the Government, hardly furnishing more than a bare living to the men who undertook the work.

In conducting the works of protection and improvement, it is of vital importance that the supply of stone shall be ample and sure, not only for securing work as it progresses, but for the economic organization of labor. The distances to which it must be transported vary from 200 to 1,200 miles, and the districts under improvement are of great extent, so that no work of bank protection, mattress construction, or dike-building can be undertaken with safety without a full supply of stone at hand, or the

certainty of its arriving within a given time. To insure this, the delivery of stone should be under the control of the general service provided with an adequate plant, and this work is quite enough to demand all the time and attention of one man, and should not be laid as an additional burden upon the district officers. The method of "open purchase" is the best and most economical for the Government at the present time, in my opinion, and I am positive that any attempt to contract for supply and delivery of stone to the works would result in disaster.

In reporting the amount of stone furnished by the general service, no account is taken of that delivered by rail at Arkansas City. Captain Sears made arrangements for that supply last season, and continued to draw from the same source after he had taken charge of the third district; about 6,000 cubic yards were on hand November 1, 1883, and 13,000 cubic yards were under contract for delivery.

The amount of stone delivered by the general service from November 1 to December 26, 1883, was 20,845 cubic yards; and from April 1 to September 30, 1884, was 75,364 cubic yards. The amount actually received from the quarries this season was 83,542 cubic yards, the average monthly output being almost 14,000 cubic yards. The average monthly delivery to the districts for the same period was 12,560 cubic yards. The average cost of delivery to the first, second, and third districts, including all expenses for steamboats, repairs, and charter, was very nearly 90 cents the cubic yard, making the average cost the cubic yard, delivered, $1.40 for sandstone, and $1.50 for limestone.

The cost of delivering stone to the fourth district for New Orleans Harbor, was not apportioned as for the other districts. The service was undertaken, somewhat to their disadvantage, to supply a pressing need. Special barges were chartered, and part of the running expenses of the boats was charged to that work for the extra time required, payment being made by the district officer.

The work of the year was by no means accomplished by the two general service tow-boats. The Minnetonka broke her shaft February 17, while taking a tow of empty barges up to the Mississippi quarries, and the Jack Frost was chartered for eight days to distribute the tow and bring her to Saint Louis for repairs. As the Minnetonka was under charter for trial at the time, the cost of repairs was borne by the owners. The Etheridge was utilized between Cairo and the quarries early in April, and was given a tow for the first and third districts on her way to the latter. Having met with an accident in May, she was sent to Saint Louis for repairs, and was used in the same manner on the return trip. While the Mississippi was engaged on a tour of inspection with the Commission, in May, the Minnetonka broke down, and the Jack Frost was chartered May 12 for eight days, and kept in service till June 6.

The Pearl, chartered in May for the first district, was taken for the general service in August for duty between Cairo and the quarries in low water. She will be kept at work till navigation closes, taking occasional tows to the first district, and may be retained in attendance on the fleet during the winter, being handier and more economical as a helper than either of the large boats.

The barge fleet also was increased at different times for special service. Between November 1, 1883, and February 29, 1884, twenty-one model barges were chartered and remained in service an average time of about eighty-two days each.

Six model barges were chartered in May for temporary use in carrying stone to the third district. In July, August, and September, sixteen model barges were chartered for special service in carrying stone to the fourth district for the improvement of New Orleans Harbor. Requisition was made in July for charter of ten model barges for use in the first district with the condition imposed that they should be without hog-chains. Very few good barges with clear decks were to be had, the market having been nearly exhausted to fill previous requisitions. Seven were obtained in July and August, and delivered loaded with stone.

Bids were invited in July for the construction of fifteen model barges, 170 by 38 by 6 feet, for the first district, but the prices ranged so much above the estimate, one bid being over $10,000, that it was not thought best to accept any. The subject was referred to the Commission which was then in session, and construction on the plans offered was not decided upon. Plans and specifications were prepared in this office in July for a special stern-wheel boat for use on Red River. The boat was finished and accepted in September and taken to Cairo, whence it will be sent with the next tow to the third district, and will steam from Wilson's Point to its destination.

Besides towing loaded and empty stone barges, the general service steamboats have taken from the several districts to the most convenient ship-yards and repair-shops, such of their plant as required overhauling, returning the same on the earliest trip after being put in order.

They have also distributed fuel purchased for the districts, and have been utilized as much as possible in carrying or towing supplies and stores bought on requisitions for them, at a considerable saving for transportation.

If the demands for such service were more regular, or for stated periods, prompt delivery could be arranged and a great reduction effected in the item of freights,

indeed, the proposed increase of the general service plant would enable me to deliver all supplies purchased for the districts.

The business has been conducted without serious accident or damage to the plant in tow, and, fortunately, without loss of life or injury to any of the crew. Minor accidents to the steamboats and annoying detentions have occurred, which interfered considerably with the delivery of stone and the return of empty barges. Barge 179, loaded with stone, was sunk at Grand Tower in May while waiting for a tow, and though several attempts have been made to raise it, they have been frustrated by sudden and unexpected rises of the river. The loss is not yet reported total, as another effort will be made, but if that fails it will be useless to try again.

On the night of May 22, barge 98, loaded with 14,600 bushels of coal, bought for the third district, was broken up and lost. The accident was due to a sudden squall during a storm, and was unavoidable. On the afternoon of June 3, boat 461, loaded with 24,379 bushels of coal, on the way to the third district, was sunk in Bullerton Chute by colliding with a barge loaded with stone. The wreck was buoyed, and as it lay out of the channel it was hoped that a portion of the cargo might be saved in low water, but the loss is total. Investigation satisfied me that the accident was unavoidable. June 17 a chartered model barge, loaded with stone, broke up and sank at Pilcher's Point. The cause of the accident has not been reported to this office.

As the tow-boats have been kept running night and day with double crews, their boilers and furnaces have required considerable repairs. The Mississippi has given special trouble and expense for new fire-sheets, but the difficulty has been remedied by substituting a vertical heater and purifier for the pan heater, and taking out the center top flue from each boiler, there having been five ten-inch flues in each.

The Minnetonka has shown signs of weakness in the cylinder-timbers, and may have to be hauled out at the close of the season to be strengthened. I recommend reducing the weight of the upper works and the area of wind-resistance by transferring the galley, pantries, and deck-rooms to the space now taken up with spare cabins and staterooms, and increasing the strength of the hull by extra stanchions and bulkheads. Should new cylinder-timbers be required, I am inclined to recommend iron.

Without taking into account the care and handling of barges at the fleet or on the reaches, the general service tow-boats have moved between quarries and the districts during the navigable season covered by this report, 1,360 pieces, equivalent to towing one piece 318,436 miles, at a cost, including all expenses for steamboat service and repairs, of very nearly 25 cents the mile. In addition to towing service, the Mississippi has made about 2,400 miles on inspection duty with the Commission.

The question of providing fuel for general service and the districts is a very serious one, and I am not yet prepared to express a decided opinion upon it.

Captain Sears bought a large amount of Pittsburgh coal early in the season, delivered in boats and barges to the fleet at Cairo, on very reasonable terms. Pittsburgh coal is probably the best for steamboat use, but I doubt whether it is so much superior to the best Illinois coal as to balance the risks and expenses attendant upon its care at the fleet. As it comes down in large tows only when the Ohio is high, it must be bought in large quantities if we wish to get it cheap; and if it is essential that we should use Pittsburgh coal, it will be better to contract for delivery to the districts, or, if more economical to receive it in one lot at the fleet, to deliver it by the general service tow-boats as soon as possible after its arrival at Cairo. Nearly 40,000 bushels have been lost this season, and I find that there has been a considerable loss every year. I believe that an amount, equivalent to that lost and incurred for care at the fleet, could be turned to good account in the purchase of a few coal barges for supplying the districts with the best Illinois coal at a considerable saving in annual expense. At the average price paid for Pittsburgh coal this year, the estimate for supplying general service tow-boats for next season amounts to $61,600. I am almost positive that I could buy the necessary fuel of good quality, and build one coal barge for the general service, and six for the districts with this amount.

A good deal of annoyance has been experienced in the management of the floating property, from the loss of barge-pumps, and careful study has been given to remedy the difficulty. A design for a fixed bilge-pump has been made, and patterns are now in hand from which a few will be cast for experiment. It is proposed to put them below decks, or to box them in, and to have the handles secured by chains. For pumping barges that are leaking badly while in tow the steam-siphon is certainly very effective; but the waste of steam is immense, even when only one is used, and the necessity for applying it might arise in a dangerous part of the river, when the full power of the engines would be needed.

The difficulty of carrying a large siphon over barges loaded with stone, and of making connections to boilers with fixed lengths of pipe, should be seen to be appreciated.

It takes considerable time to prepare the apparatus for work, and if the joints give out after it has been running for any length of time, it is no easy matter to couple them while the pipes are hot. As an improvement on this cumbrous method of pumping I devised a plan, the basis of which was to be a powerful pump in the waist of each tow-boat, which I submitted to Major Suter, of the committee. Happily he had been working on the same lines, and had used water pressure for steam with good results. The design has been modified on his suggestions by substituting a force for a suction pump, and permanently fixing small water-jet siphons in the barges alongside each hand-pump. Strong rubber hose of small diameter, with snap couplings, and in lengths convenient for a man to carry, will be used for connections, the pump having as many branches on the discharge-pipe as may be required. In cold weather low steam can be sent through from the donkey boiler to start the jet, if necessary. I feel confident that the plan outlined above will solve the problem, but I shall try it in a small way with appliances now on hand before undertaking it on a large scale.

Five thousand dollars will be ample for the complete outfit of pumps for four tow-boats, two fixed siphons in each barge, spare siphons, and a full supply of hose.

In concluding my report, I think it proper to say that the management of the general service was made easy for me by the admirable organization of the business under Captain Sears, by the forbearance of the district officers, all of whom are my seniors in rank, and by the hearty co-operation of my office force. The officers of the boats and the overseers and inspectors are excellent men, and have been faithful and efficient in the performance of their duties under all circumstances.

I present herewith a directory of the Commission, with its officers and the districts under improvement in their order, statements under appropriate headings showing the financial and working operations of this office for the year, estimates for the general service for 1885, and the general financial statement of the appropriations for "improving Mississippi River" from July 1, 1882, to September 30, 1884.

THE MISSISSIPPI RIVER COMMISSION.

Col. and Bvt. Maj. Gen. QUINCY A. GILLMORE, Corps of Engineers, President, 33 West Houston street, New York.
Lieut. Col. and Bvt. Brig. Gen. CYRUS B. COMSTOCK, Corps of Engineers, 33 West Houston street, New York.
Maj. CHARLES R. SUTER, Corps of Engineers, 1415 Washington avenue, Saint Louis.
HENRY MITCHELL, civil engineer, United States Coast and Geodetic Survey, 9 Pemberton Square, Boston.
B. M. HARROD, civil engineer, Cotton Exchange building, New Orleans.
Hon. ROBERT S. TAYLOR, P. O. box 1648, Fort Wayne, Ind.
S. W. FERGUSON, civil engineer, Greenville, Miss.
First Lieut. SMITH S. LEACH, Corps of Engineers, secretary, 2828 Washington avenue, Saint Louis.

THE COMMITTEE ON CONSTRUCTION.

Messrs. GILLMORE, COMSTOCK, SUTER, and HARROD.
Capt. JOSEPH H. WILLARD, Corps of Engineers, secretary and assistant, 2653 Olive street, Saint Louis.

OFFICERS OF ENGINEERS IN CHARGE OF DISTRICTS.

Des Moines Rapids to Illinois River, 165 *miles*.

Capt. ERNEST H. RUFFNER, Quincy, Ill.

Illinois River to Ohio River, 245 *miles*.

Maj. OSWALD H. ERNST, custom-house, Saint Louis.

First district, Ohio River to foot of Island No. 40 (*Plum Point Reach*), 220 *miles*.

Capt. JOHN G. D. KNIGHT, custom-house, Cairo, Ill., and Elmot, Ark.

Second district, foot of Island No. 40 *to White River (Memphis Reach),* 180 *miles.*

Capt. CLINTON B. SEARS, Bethell Block, Memphis, Tenn.

Third district, White River to Warrenton, Miss. (Lake Providence Reach), 220 *miles.*

Captain SEARS, Memphis, Tenn., and Wilson's Point, La.

Fourth district, Warrenton to Head of Passes, 484 *miles.*

Maj. AMOS STICKNEY, 3 South Rampart street, New Orleans.

General service estimates for 1885.

One large tow-boat, iron hull	$60,000 00		
One small tow-boat, iron hull	30,000 00	$90,000 00	
General repairs to plant	12,000 00		
Extraordinary repairs to plant	8,000 00	20,000 00	$110,000 00
Running expenses:			
Steamer Mississippi, 5 months, at $3,600		18,000 00	
Steamer Minnetonka, 10 months, at $3,800		38,000 00	
New large tow-boat, 8 months, at $3,800		30,400 00	
New small tow-boat, 8 months, at $2,600		20,800 00	107,200 00
Fuel for general service steamboats:			
Mississippi, 150 days, at 600 bushels a day, 90,000 bushels.			
Minnetonka, 300 days, at 800 bushels a day, 240,000 bushels.			
New large, 240 days, at 800 bushels a day, 192,000 bushels.			
New small, 240 days, at 400 bushels a day, 96,000 bushels.			
618,000			
618,000 bushels, at 9 cents		55,620 00	
Cost of loading, 1 cent per bushel		6,180 00	61,800 00
Office salaries, rent, and contingencies		12,000 00	
Care of fleet and property		4,500 00	
Administration and inspection		4,500 00	21,000 00
Total			300,000 00

Estimated value of the general service plant, September 30, 1884.

Iron tow-boat Mississippi	$60,000
Wooden tow-boat Minnetonka	37,750
56 stone barges	84,000
1 pumping boat	1,300
1 store boat	950
Total	184,000

Statement of purchases made on requisition from districts.

First district:
- Subsistence and general supplies, value about $34,000.
- 1,240,000 pounds of galvanized steel wire.
- 104,392 bushels of Pittsburgh coal.

Second district:
- 41,879 bushels of Pittsburgh coal.

Third district:
- 121,262 bushels of Pittsburgh coal.
- 210,000 pounds of galvanized steel wire.
- Subsistence and general supplies, value about $22,000.

Fourth district:
- Steam launch, $3,500.

Movement of stone.

Received from Mississippi quarries:			
November 1 to December 26, 1883 .... cubic yards..	10,864		
April 1 to September 30, 1884 .... do....	59,565		
		70,429	
Received from Ohio quarries:			
November 1 to December 26, 1883 .... do....	9,981		
April 1 to September 30, 1884 .... do....	23,977		
		33,958	
			104,387
Delivered to first district:			
November 1 to December 26, 1883 .... do....	15,415		
April 1 to September 30, 1884 .... do....	37,368		
		52,783	
Delivered to second district:			
November 1 to December 26, 1883 .... do....	1,034		
April 1 to September 30, 1884 .... do....	16,974		
		18,008	
Delivered to third district:			
November 1 to December 26, 1883 .... do....	4,396		
April 1 to September 30, 1884 .... do....	18,661		
		23,057	
Delivered to fourth district: In September, 1884 .... do....	....	2,361	
			96,209
On the way to fourth district, September 30, 1884 .... do....	....	4,392	
Collected at the fleet at Cairo, September 30, 1884 .... do....	....	3,786	
			8,178
Total amount furnished, delivered, and on the way, November 1, 1883, to September 30, 1884	....	....	104,387

Expenditures by Capt. Clinton B. Sears, executive officer construction department, Mississippi River Commission, from November 1, 1883, *to February* 29, 1884, *on account appropriation for improving Mississippi River, from allotments to the various reaches.*

Character of expenditure.	New Madrid Reach.	Plum Point Reach.	Memphis Reach.	Lake Providence. Reach.	Improving harbor at New Orleans.	Total.
Administration and inspection ...	....	$722 82	$240 82	$515 52	....	$1,479 16
Care of public property	....	210 59	114 97	154 04	$14 00	493 60
Fuel	....	3,793 24	....	2,256 40	....	6,049 64
Office outfit	....	....	....	7 50	....	7 50
Material and supplies	....	23,319 11	....	28,107 19	3,279 75	54,706 05
Labor	....	....	....	5,878 30	10 62	5,888 92
Plant and outfit	....	280 31	31 03	296 11	42 50	649 95
Repairs to plant	....	3,640 76	1,374 73	1,630 41	....	6,645 90
Subsistence	....	3,268 87	....	2,852 14	....	6,121 01
Transportation	....	10,034 32	82 46	11,116 76	256 99	21,490 53
General service	$1,231 06	19,095 13	2,776 36	18,711 41	....	41,813 96
Total	1,231 06	63,365 15	4,620 37	71,525 78	3,603 86	144,346 22

Expenditures by Capt. Clinton B. Sears, secretary committee on construction, Mississippi River Commission, on account appropriation for improving Mississippi River, from allotment for general service, from March 1, *to April* 11, 1884.

Office expenses	$819 56
Care of public property	645 03
Expenses steamer Mississippi	2,605 55
Expenses steamer Minnetonka	*41,025 50
Expenses steamer Etheridge	5,538 85
Expenses steamer Jack Frost	13 25
Towage and transportation	82 50
Administration and inspection	538 67
Total	51,268 91

* Includes $40,000 purchase money.

Expenditures by Capt. J. H. Willard, secretary committee on construction, Mississippi River Commission, on account appropriation for improving Mississippi River, from allotment for general service, from April 12 to September 30, 1884.

Office expenses	$4,789 53
Fuel	20,224 07
Coal fleet and care of public property	2,225 75
Steamer Mississippi	14,161 47
Steamer Minnetonka	14,546 35
Steamer Etheridge	1,193 39
Steamer Jack Frost	1,799 31
Steamer Pearl	2,858 40
Towage and transportation	1,565 68
Administration and inspection	1,906 58
Miscellaneous	3,836 25
Total	69,106 78

Classified summary of expenditures on account appropriation for improving Mississippi River, general service, from November 1, 1883, to September 30, 1884.

Services	$50,401 62
Plant and outfit	41,106 98
Fuel	31,856 01
Repairs to plant	13,001 06
Transportation and charter	9,560 63
Subsistence	8,753 00
Supplies and material	4,495 25
Mileage and traveling expenses	1,120 56
Rent and repairs	770 35
Telegrams	333 09
Stationery	205 94
Care of public property	184 80
Fuel for Capt. C. B. Sears	*121 65
Fuel and gas (office)	117 49
Water and ice (office)	83 05
Office furniture and outfit	78 17
Total	162,189 65

Expenditures under general service for plant and permanent outfit, apportioned equally between the first, second, and third districts, and operating expenses divided according to mileage service performed.

For New Madrid Reach	$1,231 06
For Plum Point Reach	60,120 63
For Memphis Reach	34,394 50
For Lake Providence Reach	66,443 46
Total	162,189 65

FINANCIAL STATEMENT.

November 1, 1883, to September 30, 1884.

GENERAL SERVICE.

	By Captain Sears.	By Captain Willard.	Total.
Drawn from Treasury	$75,000 00	$107,000 00	$182,000 [illegible]
Expended	42,232 07	78,143 62	120,375 [illegible]
Balance on hand September 30, 1884	†32,767 93	28,856 34	61,624 [illegible]

*A. R. 1851-'59.
†Transferred to Captain Willard April 11, 1884.

[...]tionment of expenditures by general service March 1, 1884, to September 30, 1884.

[...]oint Reach	$41,025 50
[...]is Reach and Harbor	31,618 14
[...]rovidence Reach	47,732 05
[T]otal	120,375 69
[...]nt third and fourth appropriations	392,000 00
[...]rred from Plum Point and Lake Providence allotment $10,000	20,000 00
[T]otal	412,000 00
	182,000 00
[...] in Treasury September 30, 1884	230,000 00
[...] in hand September 30, 1884	61,624 31
[...]le September 30, 1884	291,624 31
[...]l for construction of new plant	150,000 00
[...]ed expenditures to December 31, 1884	31,594 43
[...]ed balance December 31, 1884	110,029 88
[...]posit for sale of fuel	11 25
[...]ted amount available for conducting general service January 1,	110,041 13

PLUM POINT REACH.

	By Captains Sears and Willard.	By Captain Knight.	Total.
[...]n hand November 1, 1883	$25,365 15	$85,507 74	$110,872 89
[...]om Treasury	79,025 50	593,500 00	672,525 50
[...]al to be accounted for	104,390 65	679,007 74	783,398 39
[...]d	104,390 65	520,283 86	624,674 51
[...]n hand September 30, 1884		158,723 88	158,723 88

[...] in Treasury November 1, 1883		$51,000 00
[...]rred from unallotted balance, second appropriation		77,000 00
[...]nts from third and fourth appropriations		700,000 00
[...]ion for general service		41,025 50
[T]otal		869,025 50
[...]rred to general service	$10,000 00	
[...]rred to Atchafalaya Front	9,000 00	
[...]rred to Tensas Front, fourth district	16,000 00	
		35,000 00
[...]t available for the year		834,025 50
		672,525 50
[...] in Treasury September 30, 1884		161,500 00
[...] in hand		158,723 88
[...]le September 30, 1884		320,223 88
[...]ted expenses to December 31, 1884		243,514 15
[...]		76,709 73
[...] for loss of property		20 00
[...]ted amount available for conducting work and care of property [...]ary 1, 1885		76,729 73

NEW MADRID REACH.

	By Captain Sears.	By Captain Knight.	Total.
Balance on hand November 1, 1883	$2,427 84	$1,001 05	$3,428 89
Expended	1,231 06	56 74	1,287 80
Balance available September 30, 1884	*1,196 78	944 31	2,141 09

* Transferred to Captain Knight March 31, 1884.

MEMPHIS REACH.

	By Captains Sears and Willard.	By Major Miller.	Total.
Balance on hand November 1, 1883	$4,620 36	$19,110 00	$23,730 36
Drawn from Treasury	31,618 14	98,000 00	129,618 14
Total to be accounted for	36,238 50	117,110 00	153,348 50
Expended	37,234 68	85,487 73	122,722 41
Balance on hand September 30, 1884	—996 18	*31,622 27	30,626 09

* Transferred to Captain Sears.

Drawn from Treasury	$121,730 36
Drawn from Treasury for general service	31,618 14
Total to be accounted for	153,348 50
Expended	122,722 41
Balance in hand September 30, 1884	30,626 09
Balance in Treasury November 1, 1883	33,000 00
Allotments from third appropriation	90,000 00
Proportion for general service	31,618 14
Total	154,618 14
Drawn	129,618 14
Balance in Treasury September 30, 1884	25,000 00
Balance in hand September 30, 1884	30,626 09
Available September 30, 1884	55,626 09
Estimated expenditures to December 31, 1884	30,626 09
Estimated amount available for conducting work and care of property January 1, 1885	25,000 00

MEMPHIS HARBOR.

	By Major Miller.	By Captain Sears.	Total.
Drawn from Treasury	$40,000 00	$130,000 00	$170,000 00
Expended	28,102 74	42,685 39	70,788 13
Balance in hand September 30, 1884	*11,897 26	87,314 61	99,211 87

* Transferred to Captain Sears.

Allotment from fourth appropriation	$200,000 00
Drawn from Treasury	170,000 00
Balance in Treasury	30,000 00
Balance in hands of disbursing officer	99,211 87
Available September 30, 1884	129,211 87
Estimated expenses to December 31, 1884	129,211 87

SURVEY OF HELENA REACH.

Balance available November 1, 1883	$488 71
Expended	488 71
Available September 30, 1884	000 00

LEVEE AT LONG LAKE.

Drawn from Treasury	$1,000 00
Expended	15 55
Balance in hand	984 45
Allotment from fourth appropriation	15,000 00
Drawn	1,000 00
Balance in Treasury	14,000 00
Balance in hand	984 45
Available September 30, 1884	14,984 45
Estimated expenses to December 31, 1884	14,984 45

OPOSSUM FORK LEVEE.

Allotment, $25,000, none of which has been drawn or expended.

Estimated expenditures to December 31, 1884	$25,000 00

VICKSBURG HARBOR.

	By Captain Sears.	By Captain Marshall.	Total.
Balance on hand November 1, 1883		$5,477 60	$5,477 60
Drawn	$25,000 00	5,585 58	30,585 58
Total to be accounted for	25,000 00	11,063 18	36,063 18
Expended	17,571 51	7,770 98	25,342 49
Balance available September 30, 1884	7,428 49	*3,292 20	10,720 69

* Transferred to Captain Sears.

Available November 1, 1883		$55,477 60
Allotment from fourth appropriation		25,000 00
Total		80,477 60
Transferred to Lake Providence	$42,295 00	
Transferred to Delta Point	2,119 42	
		44,414 42
Balance		36,063 18
Expended		25,342 49
Available September 30, 1884		10,720 69
Estimated expenses to December 31, 1884		10,720 69

LAKE PROVIDENCE REACH.

	By Captains Sears and Willard.	By Captain Marshall.	Total.
Balance on hand November 1, 1883	$4,700 78	$14,627 15	$19,327 93
Drawn from Treasury	512,557 05	224,670 00	737,227 05
Total to be accounted for	517,257 83	239,297 15	756,554 98
Expended	505,539 40	187,552 16	693,091 56
Balance in hand September 30, 1884	11,718 43	*51,744 99	63,463 42

* Transferred to Captain Sears.

Balance in Treasury November 1, 1883		$137,000 00
Transferred from unallotted balance of second appropriation		67,200 00
Transferred from allotment for Vicksburg Harbor		42,295 00
Allotted from third and fourth appropriations		700,000 00
Proportion for general service		47,732 05
Total		994,227 05
Transferred to general service	$10,000 00	
Transferred to Tensas Front, third district	10,000 00	
Transferred to Yazoo Front, third district	10,000 00	
Transferred to Atchafalaya Front, fourth district	27,000 00	
		57,000 00
Balance		937,227 05
Drawn from Treasury		737,227 05
Balance in Treasury		200,000 00
Balance in hand		63,463 42
Available September 30, 1884		263,463 42
Add deposit for sale of fuel		29 25
Estimated expenses to December 31, 1884		238,492 67
Estimated balance available for work and care of property January 1, 1885.		25,000 00

NEW ORLEANS HARBOR.

	By Captain Sears.	By Major Stickney.	Total.
Balance in hand November 1, 1883	$8,430 11	—$5,577 10	$2,853 01
Drawn from Treasury	8,000 00	90,000 00	98,000 00
Total to be accounted for	16,430 11	84,422 90	100,853 01
Expended	3,603 86	60,371 98	63,975 84
Balance in hand September 30, 1884	*12,826 25	24,050 92	36,879 17

* Transferred to Major Stickney.

Balance in Treasury November 1, 1883	$106,525 90
Drawn from Treasury	98,000 00
Balance in Treasury	8,525 90
Balance in hand	36,877 17
Available September 30, 1884	45,403 07
Estimated expenses to December 31, 1884	45,403 07

SAINT FRANCIS FRONT, FIRST DISTRICT.

Available November 1, 1883	$1,687 09
Expended	1,560 20
Balance available September 30, 1884	126 89

SAINT FRANCIS FRONT, SECOND DISTRICT.

Available November 1, 1883	$787 07
Expended	787 07
Balance available September 30, 1884	000 00

MOUTH OF RED RIVER.

	By Captain Sears.	By Major Stickney.	Total.
Balance in hand November 1, 1883	$571 26	—$14,729 52	—$14,158 26
Drawn from Treasury	....	61,000 00	61,000 00
Total to be accounted for	571 26	46,270 48	46,841 74
Expended	....	28,632 32	28,632 32
Balance in hand September 30, 1884	*571 26	17,638 16	18,209 42

* Transferred to Major Stickney.

Balance in Treasury November 1, 1883	$53,000 00
Allotment from fourth appropriation	12,290 00
Total	65,290 00
Drawn	61,000 00
Balance in Treasury	4,290 00
Balance in hand	18,209 42
Available September 30, 1884	22,499 42
Estimated expenses to December 31, 1884	17,499 42
Estimated amount available for carrying on work and care of property January 1, 1885	5,000 00

NATCHEZ AND VIDALIA.

Available November 1, 1884	$5,331 42
Expended	2,658 50
Balance available September 30, 1884	2,672 92
Estimated expenses to December 31, 1884	1,672 92
Estimated amount available for conducting work and care of property January 1, 1885	1,000 00

OBSERVATIONS AT CARROLLTON.

The observations are being carried on with an allotment from the appropriation for the Mississippi River Commission.

SURVEY OF UNLEVEED FRONTS IN THE THIRD DISTRICT.

Available November 1, 1883	$503 04
Expended	502 53
Balance available September 30, 1884	0 51

SURVEY OF UNLEVEED FRONTS IN THE FOURTH DISTRICT.

Drawn	$1,000 00
Expended	902 12
Balance available September 30, 1884	97 88
Estimated expenses to December 31, 1884	97 88

SURVEY OF CUBITT'S GAP.

Available November 1, 1883	$162 96
Expended	000 00
Balance available September 30, 1884	162 96

DELTA POINT, LOUISIANA.

Available November 1, 1883	$7 64
Transferred from Vicksburg Harbor	2,119 42
Total	2,127 06
Expended	2,127 06
Balance September 30, 1884	000 00

CHOCTAW BEND SURVEY.

Available November 1, 1883	$1,320 1[illegible]
Expended	000 0[illegible]
Balance available September 30, 1884	1,320 [illegible]

This survey has been completed.

CUT-OFF AT TARPLEY.

Allotment from third appropriation	$3,000 00
Transferred to Yazoo Front, third district	3,000 00
Available September 30, 1884	000 00

LEVEES, SECOND DISTRICT.

Yazoo Front.

Balance available November 1, 1883	$1,117 75
Expended	1,117 75
Available September 30, 1884	000 00

All this allotment has been drawn.

THIRD DISTRICT.

Tensas Front.

	By Captain Sears.	By Captain Marshall.	Total.
Balance in hand November 1, 1883		$37,683 51	$37,683 51
Drawn	$25,000 00	40,000 00	65,000 00
Total to be accounted for	25,000 00	77,683 51	102,683 51
Expended	7,258 04	63,239 00	70,497 04
Balance in hand September 30, 1884	17,741 96	*14,444 51	32,186 47

* Transferred to Captain Sears.

Balance in Treasury November 1, 1883	$20,000 00
Allotted from third appropriation	10,000 00
Transferred from Lake Providence	10,000 00
Allotted from fourth appropriation	50,000 00
Total	90,000 00
Drawn from Treasury	65,000 00
Balance in Treasury	25,000 00
Balance in hand	32,186 47
Available September 30, 1884	57,186 47
Estimated expenses to December 31, 1884	57,186 47

YAZOO FRONT.

	By Captain Sears.	By Captain Marshall.	Total.
on hand November 1, 1883		$20,213 68	$20,213 68
	$23,000 00		23,000 00
otal to be accounted for	23,000 00	20,213 68	43,213 68
d	7,449 12	22,170 31	29,619 43
in hand September 30, 1884	15,550 88	—*1,956 63	13,594 25

* Transferred to Captain Sears.

erred from Lake Providence	$10,000 00
erred from cut-off at Tarpley	3,000 00
ent from fourth appropriation	20,000 00
Total	33,000 00
	23,000 00
e in Treasury	10,000 00
e in hand	13,594 25
ble September 30, 1884	23,594 25
ted expenses to December 31, 1884	23,594 25

FOURTH DISTRICT.

Atchafalaya Front.

ble November 1, 1883	$7,052 78
	24,000 00
Total	31,052 78
led	23,961 18
e on hand	7,091 60
erred from Plum Point	9,000 00
erred from Lake Providence	27,000 00
Total	36,000 00
	24,000 00
e in Treasury	12,000 00
e in hand	7,091 60
ble September 30, 1884	19,091 60
ted expenses to December 31, 1884	19,091 60

Tensas Front.

ble November 1, 1883	$174,529 19
	21,000 00
Total	195,529 19
led	192,555 82
e in Treasury	2,973 37
d from third appropriation	5,000 00
erred from Plum Point	16,000 00
d from fourth appropriation	90,000 00
Total	111,000 00
	21,000 00
e in Treasury	90,000 00
e in hand	2,973 37

Available September 30, 1884	$92,973 37
Estimated expenses to December 31, 1884	92,973 37
Total balance in hand November 1, 1883 (levees)	230,596 91
Drawn	144,000 00
Total	374,596 91
Expended	317,766 77
Balance in hand	56,830 14
Balance in Treasury November 1, 1883	30,000 00
Transferred from Plum Point	25,000 00
Transferred from Lake Providence	47,000 00
Transferred from Tarpley Cut-off	3,000 00
Allotted from third appropriation	15,000 00
Allotted from fourth appropriation	200,000 00
Total	320,000 00
Drawn	144,000 00
Balance in Treasury	176,000 00
Balance in hand	56,830 14
Available September 30, 1884	232,830 14
Estimated expenses to December 31, 1884	232,830 14

DES MOINES RAPIDS TO ILLINOIS RIVER.

Balance from former appropriations July 1, 1884	$12,663 38
Allotment, act approved July 5, 1884	200,000 00
Total	212,663 38
Expended	30,914 73
Balance September 30, 1884	181,748 65
Estimated expenses to December 31, 1884	71,748 65
Estimated balance for work and care of property to January 1, 1885	110,000 00

ILLINOIS RIVER TO OHIO RIVER.

Balance from former appropriations July 1, 1884	$9,969 15
Allotment, act approved July 5, 1884	470,000 00
Total	479,969 15
Expended	65,450 66
Balance September 30, 1884	414,518 49
Estimated expenses to December 31, 1884	147,472 37
Estimated balance for work and care of property January 1, 1885	267,046 12

PROTECTION OF EASTERLY BANK OF MISSISSIPPI, NEAR CAIRO.

Allotment, act approved July 5, 1884	$50,000 00
Expended	5.408 91
Balance September 30, 1884	44,591 09
Estimated expenses to December 31, 1884	18,591 09
Estimated balance for work and care of property to January 1, 1885	26,000 00

Respectfully submitted.

J. H. WILLARD,
Captain of Engineers,
Secretary Committee on Construction, Mississippi River Commission.

First Lieut. SMITH S. LEACH,
Corps of Engineers, Secretary Mississippi River Commission,
2828 *Washington Avenue, Saint Louis, Mo.*

APPENDIX F.

REPORT OF CAPTAIN J. G. D. KNIGHT, CORPS OF ENGINEERS, UPON OPERATIONS IN THE FIRST DISTRICT.

UNITED STATES ENGINEER OFFICE,
Cairo, Ill., October 25, 1884.

SIR: I submit the following report of operations in the 1st district, Mississippi River, between November 1, 1883, and October 1, 1884.

SAINT FRANCIS FRONT.

There has been plotted the location of the line of levees along so much of this front as lies in this district. In addition an alternate line has been run a distance of 8.75 miles from Mill Bayou to the vicinity of Barfield, which avoids caving banks, is not too remote from the river, and substitutes the closing of a small slough for that of Mill Bayou, thus leaving the latter free for the floating out of timber, a business whose prosecution, if interrupted, would endanger the levee.

STATEMENT.

Allotment		$5,000 00
Expended November 1, 1883	$3,312 91	
Expended November 1, 1883, to October 1, 1884	1,560 20	
		4,873 11
Balance on hand October 1, 1884		126 89

NEW MADRID REACH.

February 4, 1884, a preliminary project for the improvement of 33.5 miles of this reach was submitted, involving the expenditure of $179,675 for plant and $1,453,000 for construction work. With the experience gained in the Plum Point Reach, it is thought that the estimated cost of construction should be increased. Moreover, with the many changes continuing on this reach, so much of the project as related to dike work should now be modified, and that relating to bank protection extended. Caving in the vicinity of Darnell's continues with great rapidity, and a water-spout has so gullied the front of New Madrid as to render it less able than ever to withstand the cutting action of the river. This season, however, navigation through the reach has been attended with much less difficulty than last.

STATEMENT.

Allotment, less retransfers to other allotments		$212,500 00
Expended November 1, 1883	$209,071 11	
Expended November 1, 1883, to October 1, 1884	1,287 80	
		210,358 91
Balance October 1, 1884		2,141 09

PLUM POINT REACH.

Though this reach, as defined by the Commission, is 40 miles long, work of improvement has been limited to that portion of the reach bounded up-stream by Gold Dust Landing and down-stream by Yankee Bar, a distance of 13 miles. Within these limits seven different construction parties have been at work, and the reports of the various chiefs are attached. Brief reference will now be made to each of the localities occupied by these parties, taking them in their down-stream order.

Gold Dust dikes.—The condition of this work, November 1, 1883, is set forth in the report of the Mississippi River Commission, 1883 (page 365, and plate 37). Its present condition is shown in Plate IX. As at present projected, it is thought this work will be completed before the coming high water. Damage to the main dike and cross-dikes was done as described in the reports of Assistant Engineers Frith and Geuder (Appendices F 1, and F 3). Heavy fills have occurred immediately behind the main and cross dikes, which at some places are 30 feet above low-water level; the curve of low water closes below No. 5, a deposit of 12 feet having taken place since October, 1883. The openings unavoidably left in upper dikes to give access to lower unfinished ones, served at high water to give admission to heavy drift, and, on a falling river, to develop heavy scour through Elmot Chute; the drift was detrimental to unfinished work. The main dike has been reinforced by a row of piling in its front. No attempts have been made to close Dikes 4 and 5, and that to close 3 was abandoned. To continue it would have been to risk failure to close all openings above it; while its closure was not deemed essential to the turning from Elmot Chute of the flow of

the river in its lower stages. The report of Assistant Engineer George W. Gender fully describes the operations since last report, and is of interest as showing how difficulties, which might well have discouraged, were intelligently met and overcome. Attention is invited to the maps of Assistant Engineer Craig, showing condition of river in vicinity of Gold Dust October, 1884 (Plate VI), and comparisons of this with its condition October, 1883 (Plate V).

Fletcher's Field Revetment (*Plate* X).—This is to extend eventually from Mill Bayou down to near the head of Upper Osceola Chute; 493 running feet of mattress, 175 feet wide, is in place, and 800 feet of narrower mattress; the object of the latter, narrower mattress, having been to check disastrous caving promptly; 2,000 feet of high-water protection is partially laden with stone, and there is a reasonable prospect that at all points where work has been commenced, the end of the season will find the work completed in its details as far as it extends. The continuity of this work is interrupted by a heavily interlaced mass of fallen timber. As far as the power of the boat would admit, this was removed by the snag-boat John R. Meigs, temporarily placed at my disposal by Maj. A. M. Miller, Corps of Engineers, U. S. A.; for the heavier mass, it is hoped, and by the engineer officer in charge of the Mississippi River snag-boats deemed probable, that the services of one of the heaviest snag-boats could be secured to remove so much of the rack-heap as was too heavy for the Meigs. Besides this, trouble arises, as at Bullerton Tow-head, from seepage. The maximum caving in this bend between October, 1883, and May, 1884, occurred at range 33¼, and amounted to 700 feet.

Osceola Upper and Lower bars.—On pages 366–369, Report of Mississippi River Commission, 1883, is shown the condition November 1, 1883, of the dikes and bank protection near these bars. Since then Dikes 1 and 2 have needed little attention. The mass of drift in front of No. 1 was consolidated by the rise of the river and increased; the first deposit near the dike, not rising with the water, the rest floating over and lodging upon it, and more in front of it. The low-water shore-line now comes in front of the line of the dike, as shown in the sketch of Assistant Engineer W. L. Seddon (Plate XII). Behind the dike the chute is dry at a 10-foot stage, and for two-thirds of its width filled nearly to the height of the adjacent tow-head, and covered with a growth of young willows. Dike No. 3 has been closed, and repairs made at the end where the river tended to flank it. Thirty acres of drift are now accumulated above it. No revetment work has been done on the upper bar. By December 26, 1883, 2,663 linear feet of mattress, about 150 feet wide, had been sunk in front of the lower bar. The supply of material did not render practicable the resumption of work here until last August, when it was found necessary to add at the head a mattress 1,337 feet long, to connect the earlier mattress with the shore. The bank above all mattress work is now graded to a slope of 1 on from 2¼ to 3¼, and 972 linear feet are revetted with brush. It is not doubted that Assistant Engineer Seddon will have the revetment work well up with the mattress work by the end of the season. His report for this section of the reach is attached (F. 4).

Osceola No. 4 —This dike had been approximately located near the foot of Osceola Chute, but a survey in the spring of this year indicating a tendency of the river to cut across the foot of Osceola Chute and thence into Bullerton Chute, I changed the location to just below the foot of Osceola Bar, parallel to and 100 feet above range 48¼. Its length is 2,450 feet. The construction of the Arkansas end of this dike was rendered difficult by the river's taking the expected turn. Caving commenced at the bank and heavy scour set in across the dike location, giving a depth of water of 50 feet, which, however, was somewhat avoided by an offset in the dike. Large accumulations of drift have occurred above the Arkansas end of the dike during the recent rise; during August and September a fill between the rows of the dike of from 5 to 20 feet has taken place, and one of 15 feet 100 feet behind the dike. No scour nor tendency to the same has been discovered.

The report of Superintendent James M. Riley, hereto attached (Appendix F 5 and Plate XI), gives a clear, concise statement of difficulties encountered and largely by his persistent energy overcome.

Bullerton Tow-head.—At date of last report in this vicinity the revetment of the tow-head required for its completion 500 feet of mattress, 2,700 of revetment, and much distribution of stone. It has since been completed, but repeated repairs have been and still are necessary. I estimate that at the present time 750 feet need repairs which in extent will amount to renewing the revetment or high-water protection. These repairs can not be considered general, for the general condition of the work is good; but are confined mainly to special localities where their need recurs, and where seepage prevails. The total protection is 8,700 feet long; the repairs therein made during June and July, 1884, required 1,391 linear feet of mattress, 45 to 50 feet wide, 1,105 linear feet of revetment and 1,004 of grading. In July it was found to be possible to undertake Bullerton Dike No. 2, which I definitely located at the Sans Souci section of the chute. Later work was started on the closure of No. 1, of necessity left unfinished, last year's only practicable low-water channel being down the chute.

The change of direction required by deep water in No. 1 last season being no longer needed, it will be completed on the line of direction of the tow-head portion. Openings through both Nos. 1 and 2 were necessary to give access to Osceola No. 4, but orders have been given to leave drivers at No. 4 with a supply of material and close No. 1. At a higher stage these drivers can be gotten out; the season is too nearly at an end to allow of any delay in the completion of the lower cross-dikes. The sites of both of these have been mattressed their entire length; the lower dike will have a tipped mattress; the upper will not.

Superintendent A. J. Nolty's report (Appendix F 6), together with his sketch (Plate XIV), shows condition and location of work, which he has administered with energy and economy.

Plum Point Dikes.—The plate (Plate XIII) attached sufficiently indicates their location and present extent. At the close of last season 3,445 feet of dike had been built. October 1 this had been increased to 15,010 feet. In accordance with project amended by the Commission, cross-dike No. 3 has yet to be extended 100 feet; No. 4, 400 feet; and No. 5, 500 feet. Whether it will be necessary after these extensions to further extend the entire system remains to be seen. The channel-way remaining varies from 4,000 feet in width at the foot of Bullerton Tow-head to 4,800 feet at the head. Still, no extension not already projected should be more than considered until the work in Bullerton Chute, at the foot of Lower Osceola Bar, and the repairs of Bullerton Tow-head revetment are completed. The dikes so far built have served to close one channel to the left of Bullerton Bar, and will, it is hoped, tend to check the wearing away of the head of Yankee Bar.

For details of construction and statement of work accomplished, reference may be had to the report of Assistant Engineer S. P. Hatfield (Appendix F 7), whose charge of the work has been well administered.

Craighead Point Revetment.—While during previous seasons the necessity of ultimately revetting Craighead Point from Bullerton Tow-head down-stream was admitted, no immediate urgency existed. But this season the bar in front of the Lower Osceola Bar, moving down-stream, partially closed the entrance to the channel immediately along the front of Bullerton Tow-head, and the water passing mainly around the head of Yankee Bar and through Bullerton Bar united to cause rapid caving, both by direct assaults and by indirect, the latter arising from the bar formation where these two currents met, passing close to the Arkansas shore. Operations were carried on during August and September, but were attended with success in August only. Difficulties encountered during September, arising from current and drift, were not successfully overcome. The location of work done is shown in the sketch attached (Plate XV), and the disasters attending the starting of new mattresses and struggles with drift are set forth in the report of Assistant Engineer F. A. Yeager. (Appendix F 8.)

Results.—These are set forth in the report of Assistant Engineer N. B. Craig, who has had charge of surveys, and has energetically carried them on despite much sickness of himself and party. Attached to this report are—Plates I and II—a map of reach as surveyed May–June, 1884 (2 sheets); III, areas of effective low-water cross-sections, October, 1881, October, 1883, and May, 1884; and scour and deposit between October, 1881, and October, 1883; Plate VII, condition of river in vicinity of Bullerton Tow-head, low water of 1884; IV, comparison of this with condition October, 1883; VI, condition of river in vicinity of Gold Dust dikes, low water of 1884; V, comparison of this with condition October, 1883. The second shows an increase of effective area of low water between October, 1881, and October. 1883, from Gold Dust to Elmot, a marked increase at head of Bullerton Chute, and a decided decrease along Bullerton Tow-head, the decrease continuing to Craighead Point. The comparisons with May, 1884, are comparisons of low-water stages of 1881 and 1883, with a stage of 1884, intermediate between high and low, of interest as showing an increase in area of cross-section along the front of Osceola Lower Bar during a high stage. Mr. Craig's report also describes in general terms the changes in vicinity of Bullerton Bar, and gives data of importance concerning locations and extent of caving banks on this reach, notably a caving of 400 feet on Tennessee shore, 750 feet below range 25 between October, 1883, and April, 1884; a caving of 700 feet between October, 1883, and May, 1884, on Arkansas end of range 33¼; a recession down-stream between the same dates of the head of Yankee Bar, amounting to 740 feet, and a caving of 380 feet at Arkansas end of range 63½ between October, 1883, and June, 1884. Four maps (Plates VI and VII), relating to Gold Dust and Bullerton, prepared by him, give completely the changes between the low waters of 1883 and 1884, which have occurred in the immediate vicinity of dike works.

Of the discharge observations that of September 15, 1884, shows a discharge through Bullerton Chute of 23.7 per cent.; through the Tennessee Channel, 18.3 per cent.; through the Bullerton Bar, or middle channel, 31.3 per cent., and along outside of Bullerton Tow-head, 26.7 per cent. In other words, at this low water three-fourths of the river passed outside of Bullerton Chute; last low-water season only one-half passed outside. September 15, 1884, the area of Bullerton Chute discharge section was two-

sevenths of the sum of the sections of the four channels. During August and the earlier part of September Bullerton Bar re-established its claim to being an impediment to navigation. It was on record as having been such prior to improvement work commencing on this reach; but, since this commencement, had never so shown itself until this summer. About 8½ feet could be carried through for the time in question, but the channel was narrow and tortuous, scarcely deserving the name. Steamboats lightened, and in broad daylight went aground. This state of affairs confirms me in the belief that the satisfactory depth over Bullerton Bar during previous seasons should not be attributed to works then going on. Not without interest is a comparison of the reduced channel depths over Bullerton Bar, shown on Assistant Craig's outline map of May–June, 1884 (Plate II), and the depths as shown on his map of same vicinity at low water of 1884.

The low-water survey of next season and of 1886 may be expected to indicate whether or no advance is being made in securing a satisfactory low-water channel along the front of Bullerton Tow-head. This season all that can be claimed for the dikes is that they assisted in removing obstacles to low-water navigation two or three weeks earlier than nature, unaided, removed them elsewhere in the river. Next season, I believe, they will materially aid in preventing their recurrence.

The details of cost to date of work so far performed at the various stations are given in the following table.

In the case of Bullerton Tow-head Revetment the cost of completed work, per linear foot of bank, is given; but the cost of completed protection and dike-work cannot yet be given in case of the other works yet incomplete.

Estimated cost of works of construction near Plum Point, Tenn., to October 1, 1884.

Work.	Labor on construction.	Material for construction.	Subsistence.	Repair, costs, and outfit of plant.	Care of property.	Towage and steamers.
Ashport Bank Revetment	$5,149 72	$5,041 46	$2,852 27	$8,120 51	$1,091 71	$4,422 23
Gold Dust Dikes	110,018 59	107,703 56	60,934 65	173,483 94	23,429 13	94,474 93
Fletcher's Field Revetment	16,385 48	16,041 01	9,075 42	25,837 97	3,478 66	14,070 70
Osceola:						
Upper dike	9,035 44	8,845 48	5,004 43	14,247 80	1,868 40	*7,750 0[illegible]
Middle dike	9,129 06	8,937 14	5,056 29	14,395 45	1,882 14	7,8[illegible]
Cross dike	31,366 49	30,707 08	17,372 92	49,461 26	6,649 56	26,935 [illegible]
Upper Bar Revetment	5,009 27	4,903 97	2,774 48	7,899 04	1,061 96	4,301 [illegible]
Lower Bar Revetment	16,385 48	16,041 01	9,075 42	25,837 97	3,478 67	14,070 7[illegible]
Bullerton:						
Main dike	17,321 80	16,957 64	9,594 02	27,314 43	3,672 17	14,874 [illegible]
Cross dike No. 1	14,044 70	13,749 44	7,778 92	22,146 83	2,977 43	12,080 [illegible]
Cross dike No. 2	11,001 08	10,770 40	6,093 48	17,348 36	2,332 31	9,447 [illegible]
Tow-head Revetment	42,836 34	41,935 79	23,725 71	67,547 83	9,081 27	36,784 [illegible]
Plum Point Dikes	62,733 02	61,414 20	34,745 82	98,922 55	13,299 28	53,670 [illegible]
Craighead Point Revetment	5,383 80	5,270 62	2,981 92	8,489 62	1,141 34	4,623 [illegible]
Totals	355,800 87	348,318 80	197,065 75	561,053 56	75,429 08	305,535 4[illegible]

Work.	General administration of office.	Survey.	Miscellaneous.	Total cost.	Work covered by contracts.	Approximate cost.
					Linear feet.	
Ashport Bank Revetment	$553 01	$372 30	$237 74	$27,840 94	2,694	$10 34
Gold Dust Dikes	11,814 46	7,954 06	5,078 75	594,892 06	38,974	*15 25
Fletcher's Field Revetment	1,759 58	1,184 56	756 46	88,584 84	6,150	14 40
Osceola:						
Upper dike	970 30	653 22	417 14	48,796 21	7,315	†6 67
Middle dike	980 00	659 98	421 47	49,300 93	3,778	‡13 07
Cross dike	3,368 34	2,267 59	1,448 09	169,570 68	9,437	17 [illegible]
Upper Bar Revetment	537 93	362 13	231 26	27,081 64	3,100	8 7[illegible]
Lower Bar Revetment	1,759 58	1,184 56	756 46	88,584 85	4,300	20 [illegible]
Bullerton:						
Main dike	1,860 13	1,252 25	799 69	93,646 87	8,805	11 [illegible]
Cross dike No. 1	1,508 23	1,015 34	648 40	75,929 89	1,800	42 1[illegible]
Cross dike No. 2	1,181 33	795 35	507 91	59,478 29	1,400	42 [illegible]
Tow-head Revetment	4,600 05	3,096 78	1,977 62	231,586 22	8,700	†26 [illegible]
Plum Point Dikes	6,736 67	4,534 23	2,896 16	830,152 61	15,010	22 [illegible]
Craighead Point Revetment	578 10	389 22	248 54	29,106 45	1,050	27 [illegible]
Totals	38,207 77	25,721 57	16,425 69	1,923,558 48		

*$1.40 repairs. † Complete; balance incomplete. ‡ $1.07 repairs.

Estimated value of plant, first district, Mississippi River.

Craft.	No.	Original cost.	Craft.	No.	Estimated value on September 30, 1884.
'ile-drivers	37	$183,715 00	Pile-drivers	37	$131,667 00
uarter-boats	16	58,320 00	Quarter-boats*	16	29,349 00
lattress-boats	8	43,310 00	Mattress-boats	8	21,966 00
			Do †	2	10,628 00
raders	2	60,464 00	Graders	2	42,978 00
errick-boats	2	9,900 00	Derrick boats	2	6,586 00
arges	53	118,145 00	Barges ‡	51	54,832 00
lachine-boat	1	6,200 00	Machine-boat	1	5,778 00
Vhitehall boats	6	339 00	Whitehall boats	6	221 00
kiffs	63	1,416 50	Skiffs	63	1,210 00
aunch Mineola	1	3,200 00	Launch Mineola §	...	...
aunch Titania	1	1,500 00	Launch Titania	1	1,229 00
teamer Itasca	1	9,500 00	Steamer Itasca	1	9,206 00
teamer P. Kirns	1	11,740 00	Steamer P. Kirns	1	8,913 00
Total	...	509,749 50	Total	..	324,820 00

*One of the quarter-boats entirely unfit for use; $29,349 represents value of 16 quarter-boats.
† Two mattress-boats received during the period covered by present report.
‡ Two barges sunk.
§ Sunk.

The launch and barges sunk were a total loss. The quarter-boat, no longer safe float, has been floated out on the bank at high water, and now serves as a workshop.

The number of barges available has proved insufficient. Efforts to charter addi-onal ones have not been attended with much success For next season's use more arges must be built Some if not all of these should be iron, as I see no reason why ley could not be used and thereby effect a considerable saving in the annual expense repair of barges.

At least one more steamboat will be needed for long towage of brush and poles.

Details of construction of pile dikes are set forth in the report of A. J. Frith, assist-it engineer in local charge (Appendix F 1). The attention and study given by him these has resulted in a form of construction which will probably need no further odifications. With mattress laid in advance of dike construction, and in chutes, ong the entire dike location, before the dike proper is commenced, pile work can rtainly be prosecuted in 30 feet of water. But in swift currents the upper mat-ork, as tipped mattresses or wattling, should not follow pile work until the latter is ery near completion. In case of closing chutes or of a system of dikes, especial study ould be given to the order in which work is to be done Access to work in process of onstruction should be unrestricted by other work, either in like stage or already ompleted. The closing of openings left through some work to reach other is likely be expensive and slow. Longitudinal dikes, furnishing a boundary to the pro-cted channel, should not be constructed until all cross dikes in rear are built out to eir full extent. Earlier construction of these tends to prevent useful deposits of ift over areas where fill is hoped for, and access to cross dikes which may need re-airs before the results expected from them have been realized. Tipped mattresses iould be placed in the down stream dikes of a system; those intended to catch drift not need them. Their use on intermediate dikes is of doubtful utility. Revetting ds of dikes in chutes is advisable; revetting shore ends of spur dikes which are run it from convex points is of course not necessary

Though fill is proportional to height of dike, it is not recommended therefore to raise ie top of the dike above a mean stage, but to take this advantage, viz, in locations here the construction of a dike is advisable, and where depth of water does not pre-ent it, prosecute this construction during high-water stages, keeping tops of dikes lowest elevations necessitated by high water and reducing the heights as the river alls, until the tops are on a level with the mean river stage. Below this the top ne should not go.

It is advisable that cypress piling should replace cottonwood to a greater extent; the ifficulty in the way is that contracts for cypress piling are better made at the close of working season than at the beginning. Cypress brakes in this district are at a con-derable distance from the river, requiring at low water a haul too long to be con-dered, while at high water the piling can be floated out to the edge of the banks eady for rafting as required. But this otherwise timely season is generally very un-imely for the reason that funds are then almost exhausted, and it is not known hether another appropriation will be passed by Congress or when it may be av-

pected. Hardly a proper condition of affairs with which to enter upon a contract for a delivery of material.

Protection work has not yet proved an entire success. While in depths of from 50 to 70 feet it seems probable that a bank can be held against assaults from the water side, the method of protecting a bank from the influence of seepage water has not yet been devised. Trouble with drifts may be obviated by the use of fender barges to slant the drift from the head and flank of a mattress. Care should be taken that the close of the working season finds all mattress work accompanied by corresponding completed upper bank protection; otherwise it will probably be necessary the following season to construct another interior mattress.

The question of timely supplies of material is still troublesome, though less so than in former seasons. But with a large increase of force engaged in protection work, to obtain the requisite supplies of brush and poles will be no easy matter. At high water the willow camps are overflowed. At intermediate falling stages they are quagmires, and at low water many of them are inaccessible to barges and steamboats. The importance of this subject may be seen when it is known that during the period covered by this report there have been used on this reach 32,591 cords of brush and 3,729 cords of poles.

All work has been done by hired labor. In purchasing brush, piles, and poles, written sealed proposals have been obtained in response to circular letters to principal dealers. The prices paid for these articles are, piles, 3¾ cents per running foot delivered at the works; brush and poles delivered on barges at $1.07 and $2 per cord respectively. Fresh beef has been supplied under contract at 7 cents per pound. A large amount of wire was contracted for by the purchasing agent of the Commission, and proposals have recently been received, after advertisement, and accepted, for supplying grocers' supplies, canned fruits and vegetables, salt meats, and millers' supplies. One contractor, C. Mark Cole, having failed in his delivery of piling, moneys due him at the time of failure were, as per agreement, forfeited to the United States.

Work to be done in accordance with existing projects and between Ashport and Craighead Point is approximately as follows:

	Feet.
Ashport to Gold Dust Revetment	18,000
Mill Bayou to head of Osceola Chute Revetment	18,500
Upper Osceola Bar Revetment	3,000
Lower Osceola Bar Revetment	5,500
Upper side of Craighead Point Revetment	14,000
Total	59,000
Gold Dust Dikes	1,400
Osceola No. 4 Dikes	300
Plum Point Dikes	1,000
Bullerton Nos. 1 and 2 Dikes	1,000
Total	3,700
In addition it may be thought advisable to revet head of Yankee Bar	2,000
Revet head of tow-head to the west of Island 30	400
Total	2,400
And to construct spur dike near foot of Elmot Chute	1,500
2 spur dikes at Plum Point	1,200
Total	2,700

Projected work:	
59,000 feet of revetment work, at $25	$1,475,000
3,700 feet of dike work, at $25	92,500
Suggested work:	
2,400 feet of revetment work, at $25	60,000
2,700 feet of dike work, at $22	59,400
Total estimated cost	1,686,900

It is thought that this construction work will continue to increase in cost; the difficulty of getting material continually increases, and with this the cost. Moreover, methods of revetting banks influenced by seepage will be more expensive than the ordinary bank protection.

STATEMENT.

otments from appropriation of—	
March 3, 1881	$568,095 18
August 2, 1882	1,077,000 00
January 19, 1884	365,000 00
July 5, 1884	300,000 00
llected from employés for lost property and deposited in United States Treasury	20 00
portion of allotments for general service charged to Plum Point Reach	41,025 50
Total	2,351,140 68
pended to date	2,030,896 80
Balance	320,243 88

)f this balance $130,723.88 are drawn from the Treasury, $28,000 are in transitu, d $85,000 applied for, for use in November, 1884. Hence, $76,520 is the estimated lance December 1, 1884, for prosecuting work and caring for plant until another propriation is made.

Feneral matters relating to the first district.—On the Plum Point Reach a study of ices requiring attention develops many where the need of protection is urgent, and on with the district itself. Excessive caving characterizes the vicinity of Hickn, Columbus, New Madrid Bend, and the bend of Island 35, and considering its sible effect on the first district, I trust I may be allowed to invite attention to the d opposite and below Cairo. Should systematic bank protection, progressing wn-stream from some determined origin, be undertaken, that origin should be ced above Cairo on the Mississippi. But such progressive work will be slow, and the mean time it would be well to undertake, simultaneously, such as will tend to prove the river where caving is progressing with exceedingly injurious rapidity.

)f these points, it certainly needs no defense to select, other things being equal, se where damage being done to property is greatest. Such a selection would ange the points above named in the following order: Bird's Point, New Madrid nt (not Bend), Island 35 bend, Darnell's (New Madrid Bend), Columbus, and Hickn.

'he following table gives the total expenditure on the first district, and also includes ,636.68 liabilities incurred.

Statement of money disbursed, first district, Mississippi River.

	Plum Point.	New Madrid.	Saint Francis Front.
eral administration	$117,458 74	$683 98	
e	20,749 03	21 00	
of property	75,429 03	18 50	
struction of plant	476,361 46	193,549 99	
mers, towage, &c	324,943 44	7,296 50	
sistence	197,065 75		
rey	25,721 57	4,555 69	$4,873 11
or on plant	161,696 88	20 00	
or on construction works	355,800 87		
erial for construction works	348,318 80		
rters	37,562 22		
cellaneous	16,425 69	4,213 25	
To date	2,057,533 48	210,358 91	4,873 11

ended as per report, 1883	$1,573,057 25	Plum Point	$2,057,533 48
ended since	699,708 25	New Madrid	210,358 91
		Saint Francis	4,873 11
	2,272,765 50		2,272,765 50

Very respectfully,

JOHN G. D. KNIGHT,
Captain of Engineers, U. S. A.

Lieut. Col. C. B. COMSTOCK,
Corps of Engineers, U. S. A.,
President Mississippi River Commission.

F 1.

REPORT OF ARTHUR J. FRITH, ASSISTANT ENGINEER, UPON THE IMPROVEMENT OF THE MISSISSIPPI RIVER AT PLUM POINT.

UNITED STATES ENGINEER OFFICE,
Elmot, Ark., October 1, 1884.

CAPTAIN; I have the honor to make a report on the improvement of the Mississippi River at Plum Point, Tenn., covering the period between November 1, 1883, and October 1, 1884.

By reference to map (I and II) accompanying Assistant Craig's report it will be seen that the work on this reach may be divided into five distinct stations or points of operation, the objecct of which is to concentrate the bulk of water within a single channel.

1. The closing of the chutes between Elmot Bar and the Tennessee shore by the main and cross dikes at and below Gold Dust.
2. The protection of the Arkansas shore from Fletcher's Landing to Elmot against the continual encroachment of the river.
3. The closing of the chutes between the Arkansas shore and Osceola Bars and Bullerton Tow-head and the protection of the river banks of the latter island.
4 The encroachment of the Tennessee shore upon the river bed by main and cross dikes below Plum Point.
5. The protection of the Arkansas shore below Bullerton Tow-head against further caving.

On November 1, 1883, and previous to the high water, the condition of these several scenes of operations were as follows:

At Gold Dust there was a main dike running from Gold Dust to Elmot Bar and seven cross-dikes between it and the Tennessee shore, namely: Cross-dike No. 1, No. 1 A, No. 1 B, No. 2, No. 3, No. 4, and No. 5. The portions of these dikes lying upon the continuation of Elmot Bar were of the earlier type of construction and are deemed weak.

Those nearer the channel portion are in accordance with later specifications and of much better construction.

There was a continuous line of openings through the main and cross dikes, following the line of deepest water.

This channel had been imperatively necessary for the supply of material to the various localities where work was in progress, and as this is essentially a high-water chute, that is, its greatest current and discharge being during the higher stages of the river, it was earnestly desired that all our work should be in a condition to withstand the attack of the coming season. Lack of material furnished, due greatly to the inclemency of the weather, rendered futile the attainment of this object. The opening in Cross-dike No. 5 was closed and mattressed, but that in No. 4 was only partially finished, and the other openings were all clear and wide. On the main dike and bar end of Cross-dike —, foot and tipped mattresses were finished, but were weighted in many instances by sand-bags in place of rock. At Station 2 the protection of Fletcher's Bend had not been commenced. At Station 3, Osceola Cross-dike No. 1, between Upper Osceola Bar and the Arkansas shore, was complete with heavy drift piled in front and some fell behind it. This, as well as Osceola No. 2, further down the chute, was thoroughly inspected and braced with wire cables during the end of the season.

Osceola Cross-dike No. 3, between Lower Osceola Bar and the Arkansas shore, was finished and mattressed. The inner shore of the bar was mattressed and the outer shore for 3,583 feet was protected by mattress 150 feet wide, of which the latter portion was sunk just previous to the final rising of the river.

In Bullerton Chute the closing was but partial, since the steamboat channel ran through it, and the final work could not be done until a passage was found elsewhere.

At this point there was the main dike between Osceola Bar and Bullerton Tow-head and Bullerton Cross-dike No. 1, which, with the exception of the opening for steamboats, was completed and mattressed. Bullerton Tow-head was mattressed throughout its entire length, and we were able to finish and load the entire high-water protection before the final rising of the river.

At Station No. 4, Cross-dikes Nos. 1 and 2 and the main dike to the latter were driven with an opening just above No. 1. Of this, No. 1 and the main dike above it were finished with foot and tipped mat, but No. 2 and the lower end of main dike were unmattressed.

At Station No. 5 no efforts had as yet been made to protect the Arkansas shore.

During November the river rose from 9 to 18 feet, and fell again to 7 feet on December 25, when, accompanied with ice, the winter rise set in. This first rise was sudden and pressed us closely. Its first effect was to increase the current in Elmot Chute, Station No. 1, to a dangerous extent, especially at Cross-dike No. 5, where the channel

s narrow, and to cause large accumulations of drift on the main and cross dikes. At No. 5 the head of the water was beyond all expectations, being estimated to be from 14 to 18 inches, and at the main dike much less, probably not over 5 or 6 inches. No. 5 dike stood this enormous pressure of over 2 tons to the running foot in the deepest portion for some time. Then the forward brace gave way, and the front line fell back on the second. It remained thus for a time, but with violent shaking of the individual piles and clusters, when it finally broke in several places. No. 4 was also damaged, but all other portions were uninjured. Efforts were made to repair the damage, but rising water and ice soon put a stop to all operations.

At Station No. 3 the effect on Osceola No. 1 was most interesting; at the first rise one-half of the accumulation of drift 600 feet wide in front of the dike apparently narrowed and then filled out again, caused by the drift next to the piling being buried and anchored; so thus on the water rising, the accumulation behind rose and floated over it. There was no current behind this dike.

At Osceola No. 3 a vast amount of drift lodged against the dike, pressing it back n the center, where we were driven out at low water before completing it; for a time this threatened a total destruction, but timely efforts soon strengthened this portion, and no damage was sustained.

Bullerton main dike and Cross-dike No. 1 also showed accumulations of drift, but no harm was done.

At Station No. 4, the only effect of this rise was to show a noticeable fill behind the dike of from 5 to 10 feet, but the high water and floating ice put a stop to field operations and forced us into winter quarters.

The crest of the rise was reached at this point February 27, 1884, when the guage showed 32.05 foot above low water of 1879.

As much of the Gold Dust, Bullerton, and Plum Point dikes reach but to the height of the 15-foot stage, they were, of course, covered at the higher stage of the river. Osceola Nos. 1, 2, and 3, and parts of Bullerton No. 1 and Plum Point dikes, approached the high-water level and held large amounts of drift. We closely watched for the different effects that might be ascribed to this difference of height, and found that the height of fill was in almost direct ratio to the height of the dike.

Slack water prevailed behind the artificial rafts of drift at Osceola Nos. 1 and 3 and n Bullerton Chute, the latter due to the chute being a low-water chute, where alone a heavy current is induced by resistances in front of Bullerton Tow-head at low water.

Our experience in the early winter had warned us that improvement in our standard of dikes would be advisable in three particulars:

1. That with deep water and excessive width of dike it would be advisable to use more than three rows of piling, for where the distance apart of the pile rows was greater than 25 feet the braces were greatly weakened by their own weight.

2. That the former fastenings by drift-bolts and wire were exceedingly uncertain, the drift-bolts splitting the piles, and the wire wrappings being often loose and of unequal tension, when a dike was subject to great shaking of the piles, as at No. 5, Gold Dust. This might cause failure even under moderate pressures.

It has therefore been our practice during the past season to use no drift-bolts, and to bind every intersection of dike with short cables, 15 to 20 feet long, made of 16 strands of No. 12 wire or its equivalent. These are drawn tight with a winch, securely lashed, and renders these joints by far the strongest portion of the dike.

3. The tipped mattress is made upon piles slung within the dike and either hung from the center row with two cables running to top of front pile or lashed to center piles, and with cables to front row. This lessens the danger of breaking of the supports of mattress, brings the strain upon the dike in a manner deemed most beneficial, and free motion is allowed the lower end to follow any scour that may occur. Fig. , Plate VIII, is a plan, elevation, and section of this dike, showing how the width, number of rows, and number of piles in clusters vary with varying depths, also difference in bracing and tipped mattress in shallow and deep water. As the water fell, trouble was experienced with the revetment on Bullerton Tow-head, on which portions would slide down, carrying brush and stone with it. This was due mostly to seepage from lakes in the interior, the drainage of which afforded but partial relief. This action threatens to be a very serious one, and experiments have been in progress during the summer, details of which may be found in Assistant Nolty's report, with the object of draining the banks. Our results, however, do not promise much, unless the impervious clay layer existing in nearly all banks along which the water flows, and from which the seepage caving commences, unless the layer is above low water, when drainage, such as Fig. 2, will probably be effective. When the layer is below low water two different methods are in progress of trial:

First (Fig. 3), a heavy mattress or retaining wall is built and sunk at the foot of the bank and heavily loaded with stone.

Second (Fig. 4), clusters of piles are driven 5 feet apart along the bank, which pierce to the hard strata below; inside of this fascines of brush and drift are piled till the space is filled.

Both of these methods aim to allow the water to pass through, while the material is held back and a resistance offered to the sliding of the bank.

It is not deemed necessary to prepare the entire bend in this manner, but only those spots where this action has taken place, it being believed that there exist lines of subdrainage along which the bank waters will always flow, and hence that the points of attack are local and determined by pockets, previous actions and dipping of the strata.

Upon the subsidence of the high water it was seen that our work had not only suffered very little, but that heavy fills were formed behind all our dikes. At Gold Dust, behind the higher portions of the main dike, the fill, varying from 12 to 15 feet, reached the top of the piling, and parts of the cross-dikes were buried. On the lower portion nearer the chute channel the dike was clogged with drift, and the fill, though continuous, was not so high. Recent surveys show that the curves of low water this year have drawn together, giving a total fall in this chute of 3,000,000 cubic yards.

The action of the tipped mattress showed very markedly that their lower edge follows quickly any scour at that point, while the eddying behind is much reduced.

During high water there was one break of about 400 feet in the main dike, caused by a local obstruction which destroyed some of the fill in the higher part of the bar, and many piles along the front row of the main dike had been broken by drift, which had here done considerable damage.

At Station No. 3 the fill behind Osceola No. 1 reaches to the top of the dike, and leaves but a small chute next to the Arkansas shore, which is closed at about the 12-foot stage.

All except this little chute is now covered with a thick growth of small willows, and the chute may be considered permanently closed.

At Osceola No. 3 a vast accumulation of drift lies before the dike, and fills, varying from 10 to 25 feet, have taken place behind it, and a general fill of 6 to 8 feet in front, the mattress on the inside of the bar being buried and the upper bar tailed down to the dike. This chute is now dry at about the 12-foot stage of the river.

The mattress on the front of Osceola Bar, though without shore protection, stood well, but a small portion of the head of the island having caved away, makes a sub-mattress necessary before the revetment can be finished.

Bullerton main and cross-dikes No. 1 had large fills back of them, that behind the latter now bearing a crop of low willow. Thus the former channel of the river would have been closed at low water had not the current later in the season broken through just at the foot of Osceola Bar, rendering the construction of Osceola Cross-dike No. 4 necessary.

This will, however, be mentioned later on. The fill behind the Plum Point system of dikes, as far as constructed, was as high as 25 feet, except at the opening in the main dike, where it was only small. The height of the deposit was almost in direct ratio to the height of the dike, while the tipped mattress at low water lay on the f[illegible] of the deposit as a revetment, and is growing in many places. When the water h[illegible] fallen sufficiently work was commenced on the repairs and to finish the Gold D[illegible] system of dikes (Station 1).

This consisted in driving a new dike in the 400-foot break in the main dike, and running another row of piling on the face of the dike for 4,475 feet, where it had be[illegible] injured by drift, and in weighting with stone portions of old tipped mattress forme[illegible] sunk with sand-bags, which had proven most inefficient.

When attempts were made to close the openings in the main and cross dike[illegible] was evident that in the lower dikes the depth had so increased during the win[illegible] that work was nigh impossible, and our efforts had been confined to the closing [illegible] mattressing of Cross-dikes Nos. 2, 1 B, 1 A, 1, and the main dike.

The current was very severe at this point, and at your suggestion mattressing p[illegible] ceded the pile work. This was accomplished by driving clusters, from 15 to 25 f[illegible] apart, some distance above the dike from which the mattress is built, either conti[illegible] ously or in sections of 100 feet or more down-stream, with cables running to the [illegible] of the clusters (Fig. 5). This method has proved very successful, and has been u[illegible] on most of our channel dikes this season.

At this date all main and cross dikes, Nos. 1 and 1*a* openings, are closed, and work will undoubtedly be finished by the end of the season. At Station 2, Fletch[illegible] Bend had caved badly during the winter, and the falling trees had left a mass of sn[illegible] in some places 100 feet wide, and matted into a jagged mass that, until removed, [illegible] dered mattress work impossible. The snag-boat John R. Meigs was borrowed f[illegible] the Memphis Reach, and from the 19th of May to 17th of July she did good work, [illegible] was finally obliged to abandon quite a stretch of bank, not being powerful enoug[illegible] handle the snags encountered. We have therefore left this portion, but have [illegible] structed above it 3,181 feet of mattress 175 feet wide, requiring .59 cords of brush [illegible] .56 cubic yards of stone to the 100 square feet, and below 1,750 feet with banks gra[illegible]. We trust to have all finished before high water.

At Station No. 2 no work was necessary on Osceola Dikes Nos. 1, 2, and 3, and late in the section 1,337 feet of mattress was constructed on Lower Osceola Bar to connect the old mattress thoroughly with the banks graded; all this will be brushed and loaded this season. At the foot of this bar it has been mentioned that after the first fall in the river the water broke through the upper portion of the old main dike, and was cutting a channel through the deposit at the foot of the bar. To counteract this tendency Osceola Dike No. 4 was commenced May 12, 1884, and runs from the main dike to the Arkansas shore just above range 48½. Except near the Arkansas shore most of this dike is driven on the bar and has been matressed. From a portion of it we were driven out by a falling river, and must wait for the fall rise to finish it. In the channel near the Arkansas shore the water was rapid and deep, 50 feet in one place, and this portion of the dike was driven under considerable disadvantage with five rows of piling; since then it has collected a large amount of drift. The current has materially slackened, and a deposit of from 15 to 20 feet has been found during low water. In Bullerton Chute the completion of Cross-dike No. 1 and the construction of No. 2 will be finished before the close of the season. With both these dikes mattressing preceded the pile work, which varies from 3 to 4 rows, according to the depth. No. 2 will be tipped-mattressed its entire length.

At Station No. 4, Plum Point system of dikes, work was started early in the spring before the water had fallen, and has been in progress throughout the season.

Cross-dikes Nos. 2, 3, 4, 5, and 6, and part of the main dike, have been finished, all of which, except No. 6, will be tipped-mattressed, and are of the strongest dimensions. Their effect has already been beneficial, turning the water out of the Yankee Bar Chute. They have undoubtedly contributed materially to the maintenance of a steamboat channel during the low-water season.

The work done at this point has amounted to 12,057 feet of pile dike, 470,425 square feet of foot mattress (grillage), and 255,730 square feet of tipped mattress. The conditions for maintaining good steamboat water at Bullerton this season have been most unfavorable, the water being divided between a channel around Osceola Bar and through Osceola Cross-dike No. 4, one through Bullerton main dike and chute, one crossing to the head of Bullerton and along the outside shore, one by a channel through an extension of Yankee Bar, and by another channel along the face of Yankee Bar. The first and last of these were obstructed by Osceola No. 4 and Plum Point dikes, while the steamboat water changed from crossing over to head of Bullerton to the fourth or bar channel, and then back again, giving at present plenty of water and a straight passage. Station No. 5, or the protection of Craighead Point, was not commenced until somewhat late, when the cutting away through the bar in front of Yankee Bar impinged the current directly against the bank.

One section of mattress 150 feet wide has been placed at this point, but a second section, though built extra strong, broke 14 lines—1¼ and 2 inches diameter—and tore itself loose. The current at this point being very swift, another section of mattress, with grading and protection of bank, yet remains to be built. I may add that the supply of piles and brush, though not always in quantities as large as might have been desired, has been much better than in years previous, and the establishment of the rock depot at Gold Dust has been of very material aid.

The working plant in use consisted of 37 pile-drivers, 15 quarter-boats, 10 mattress-boats, 2 graders, 2 derrick-boats, and 53 barges.

Details of the operations at different stations will be found in the reports of the several assistants, to whose energy and devotion to their work most of our success is due.

Respectfully submitted by

ARTHUR J. FRITH,
United States Assistant Engineer.

Capt. JOHN G. D. KNIGHT,
Corps of Engineers, U. S. A.

F 2.

REPORT OF GEORGE W. GEUDER, ASSISTANT ENGINEER, UPON OPERATIONS OF GOLD DUST, TENNESSEE.

GOLD DUST, TENN., *October* 1, 1884.

SIR: I have the honor to submit the following report on the progress of the work at Gold Dust from November 1, 1883, to October 1, 1884 (Appendix F 3 and Plate IX):

A history of this work to November 1, 1883, was given in my last report.

Its location is shown upon accompanying sketch (Plate IX). Work at this locality

was in progress continuously from November 1, 1883, until the season was closed by the high stage of the river; resumed June 17, and continued to the time of this writing. It is thought that the Gold Dust dikes will be completed before the coming high water can interfere with construction.

Advantage was taken of the low water of 1883, and the pile work of the main dike pushed vigorously, completing the dike, with the exception of an opening of 300 feet in length, which had to be left to enable the boats to reach the parties at work on the lower cross dikes, before November 1, 1883.

The foot-mat party, with the available plant, was unable to keep up to the pile work, and the high water arrived before the foot-mat in front of the dike could be completed.

The grillage mat between the piling was placed for the entire length of the dike. The following mats were constructed before operations had to be suspended on account of high water. The 100-foot tipped foot-mat was continued for 305 linear feet. It was found by inspection after the high water went down that the pressure was too great for the supports of this mat, and either broke the riders of the dike or the piles by which the down-stream edge of the mat was held at the level of the riders of the dike. The tipped grillage of which 1,884.1 squares were constructed, had the same weakness. Where tipped grillage or foot-mat remained in their original position, they were a decided success, causing large deposits to form immediately under them.

Wattling previously commenced was completed to top of piles for 700 linear feet = 82.7 squares. It was deemed advisable to place a foot-mat, 50 feet wide, directly in front of the main dike, between Cross-dikes Nos. 3 and 4, to prevent any parallel scour, and 775 linear feet, equal to 387.5 squares, were placed, when high water prevented further operations. A portion of this mat was constructed on the dry bar, and where it was possible the mat was wired to the tipped grillage. Later events proved the wisdom of this step; for during the high water a scour parallel to the dike took place deep enough to wash out some of the piles at the lower end of the dike, where the foot mat could not be completed. At the Tennessee end of the main dike 68.8 squares of bank protection were constructed and loaded with rock. During the high stage of the river piles were driven through the bank protection and the main dike extended toward the Tennessee shore for 100 feet.

This portion of the dike running up on high ground it was deemed sufficient to build it of a single line of piles.

The dike has had the desired effect of causing heavy deposits immediately in the rear of it, and but little damage was done to it by the protracted high water.

After the high water went down, one breach of 400 feet was discovered just below Cross-dike No. 3. The damage by this portion giving way was entirely local. The current after passing through the opening soon lost its force, and beyond scouring out a deep hole immediately behind the dike, did no harm.

At this gap the difference of slope on the chute side, and the main river was so great, caused by Cross-dike No. 3 just above it, and obstructions in front of the main dike just below the gap, as to render the current extremely rapid through this portion of the main dike, resulting in scouring under the mat deep enough to wash out the piles. A similar scour has taken place below Cross-dike No. 4; and to guard against like injury, the protecting mat of the main dike will have to be built especially thick and wide, and well loaded with rock for some distance below each cross-dike. The pile work of the main dike should be strongest at a cross-dike, and decrease in strength to the next cross-dike below. Where the dike was high it was damaged more or less by heavy masses of drift resting on riders and braces, and crushing these by their weight after the water had fallen. That portion of the dike driven to a 15-foot stage remained almost intact.

The bar which formed immediately behind the main dike, between Cross-dikes Nos. 3 and 4, is almost as high as the dike for the entire distance. The crest of the bar is 30 feet above the level of the low water of 1879. From Cross-dike No. 3 to the opening left for passing material the fill gradually decreases and is nothing at the down-stream end of the opening. At the Tennessee end of the main dike the material has been deposited as high as the main shore, and a level bar almost as high as the dike extends to the up-stream end of the opening. During the higher stages of the river a fill took place below the opening, but the river falling below a 15-foot stage, almost all the water passing down Elmot chute rushed through this opening with great rapidity, scouring to a depth of 20 feet before it could be protected by a foot-mat.

The crest of the bar in front of the main dike within the space allotted to the channel was lowered from 10 to 12 feet during high water.

On June 17, after the high water had passed, pile drivers resumed operations, and immediately commenced closing the breach in the main dike, below Cross-dike No. 3. They barely succeeded in closing the second and third rows, when it became necessary to withdraw them from the opening, the water shoaling so rapidly. Pile-drivers then commenced repairing the damaged riders and braces of the high portion of the main dike. It having been discovered that the front row of this portion

f the dike, where it had not been protected by a foot-mat directly in front of it, had een almost washed out by the scour parallel to the dike, it was deemed advisable o drive a new front row with piles spaced 5 feet between clusters, this spacing being mployed to prevent, if possible, the breaking down of riders and braces by the heavy rift. After completing 4,475 linear feet, the pile-drivers were transferred to the ross-dikes.

On August 1, the foot-mat party returned to Gold Dust, and commenced the contruction of a foot-mat in the opening of the main dike left for passing material, hich was scouring rapidly. The current was very swift, and to be able to sink he mat successfully every precaution had to be taken in its construction. While eing constructed the mat was held in place by wire cables fastened to clusters, which ere driven on a line about 75 feet above the line of the dike. The clusters were riven 20 feet apart, and consisted of three piles, each pile having a cable fastened o it at the bottom of the river. To prevent the swaying and working out of clusers the piles of each cluster were driven some distance apart, drawn together at the op, and firmly lashed with No. 8 wire. The mattress boat was placed at right angles o the line of the clusters and the cables fastened to the mat while it was being fabriated. Four men were able to fasten these well, as fast as the mat was constructed. n the swift current the cables leading to the bottom of clusters would have a tendncy to pull the mat under water as soon as it was launched from the mattress-boat; o prevent this wire cables were fastened to the top of clusters and kept short enough o prevent a strain on the lower cables. While sinking the mat the top cables were nt some distance in advance of the rock barge. The mat was sunk at right angles o the current, damming up the least possible amount of water. At the cross-dikes ats over 600 feet long have been sunk with little difficulty. In the opening of the ain dike 468.5 squares of foot-mat were placed.

Before the November rise arrived all the cross-dikes had been completed with the xception of an opening left for passing material. Had the low water lasted as long s that of the preceding year all openings would have been closed. The water, finding a straight channel through these openings, rushed through them with great veocity, and the heavy masses of drift striking the ends of the dike damaged them to uch an extent that the new dikes had to be driven below the old ones, overlapping hese as far as it was deemed necessary. Completing the cross-dikes was very slow ork. Steamers could not bring the material to be expended down Elmot chute on ccount of snags and sand-bars, and nearly all the material had to be towed by hand rom a distance.

The moving of barges and material from one point to another forms a large item n this work. At Cross-dike No. 1 advantage was taken of the rise, during the latter art of November, to connect the Tennessee end with the main shore. Ninety feet of ike of two rows were constructed, completing the dike with the exception of an openng left for passing material. This dike was driven to a 15-foot stage, and during the ast high water almost all of it was completely covered with sand.

The construction of the Tennessee end of Cross-dike No. 1*a* was pushed at the same ime Cross-dike No. 1 was building, completing 125 linear feet of dike of three rows. Between the second and third rows 190 squares of tipped grillage were placed. The igh stage of the river prevented the construction of grillage mat between the first nd second rows. During high water the north end of this dike was slightly damged by drift.

Where the tipped grillage remained in its original position the fill is nearly as high the dike and extends to Cross-dike No. 1[b]. At the junction of this dike with the ain dike, 150 linear feet of dike of two rows were constructed during September. A ot-mat 100 feet wide and 542 feet long = 542 squares, has been sunk across the entire ening, and 38.5 squares of grillage constructed at the north end of the dike. Operans were continued at Cross-dike No. 1[b], and before they had to be suspended on acunt of high water, 206 feet of dike were constructed at the south, and 528 feet at e north end. A good fill took place below this dike during high water. A bar havg formed between the north end of this cross-dike and the main dike, it was deemed practicable to continue it northward. A foot-mat 100 feet wide and 635 feet long as sunk across the opening, and 620 feet of dike of three rows driven through it, mpleting the pile-work of this dike. That portion of the dike driven before high ater has since been protected by 188.95 squares of grillage.

To prevent any scour between the Tennessee shore and the end of Cross-dikes Nos. 3, and 4, a mattress from 50 to 100 feet wide and 325 feet long was sunk, the perpenicular caving bank graded, and the bank protection carried to the top of the bank. hese protections have served to prevent any caving, and the willows of the bank rotection are growing nicely.

At the Tennessee end of Cross-dike No. 2, 267.5 squares of mattress and 195 quares of bank protection were placed. The bank was graded for 325 linear feet = ,599 cubic yards. At the bar end of this dike 591 feet of dike of two rows and 233 eet of three rows were completed before operations had to be suspended on account

of high water. A grillage mat was commenced at the north end of the opening, but only 20 squares could be completed before the riders of the dike were submerged.

This dike shows good results by the shoaling of the water behind it and the enlargement of the bar.

During the month of August a foot-mat 100 feet wide, 763 feet long, was sunk across the opening, and the old dike protected by 268.52 squares of grillage. A dike of three rows 668 feet long has been driven across the opening, completing the dike.

The shore protection for Cross-dike No. 3 was completed to the top of the bank, constructing 270 squares of bank protection. On the bar side of the deep channel a tipped foot-mat was commenced, but only 153 squares could be completed before the dike was submerged. At the bar end 55 squares of grillage were constructed, completing the grillage for this dike, with the exception of a section about 90 feet long, which could not be placed before high water prevented its construction, and during the high water this portion of the dike was scoured out, causing the only breach.

Drift damaged the end of the dike at the opening severely. A large fill has taken place above and below that portion of the dike between the breach and the main dike, but south of the gap hardly any fill can be noticed. In the channel near the Tennessee shore a deep scour took place, which made the closing of openings in Cross-dikes Nos. 3, 4, and 5 impracticable. During the month of August 170 squares of foot-mat were constructed below Cross-dike No. 3 before orders were received from you to suspend operations, it being impossible to obtain piles of sufficient length and in sufficient quantities to close the opening. At Cross-dike No. 4, 135 squares of bank protection were constructed, completing the shore protection; and on the bar side of the channel 242.5 squares of tipped foot-mat were constructed before operations had to be suspended.

The grillage mat was completed for the entire length of the dike, constructing 350 squares, commencing at the main dike, 2,250 feet = 1,012.5 squares of tipped grillage, were placed on the up-stream side of the dike.

The grillage mats at Cross-dikes Nos. 4 and 5 and at the main dike between Cross-dikes Nos. 3 and 4 were constructed on the dry bar, the necessary brush being supplied from the head of Elmot Bar.

To save the transportation of rock across the bar tarred sacks filled with sand were substituted. During high water the sand was washed out of the sacks by reason of their loose texture, allowing the swift current to scour under the mat deep enough to wash out the piles. The tipped grillage in front of the north end of the dike was a decided success, it having been completely covered with sand during high water.

The tipped grillage in front of the bar end of Cross-dike No. 5 was continued for 660 feet = 330 squares, and at the Tennessee end 45 squares were constructed before operations had to be suspended. Wattling was placed on piles above the tipped grillage for 90 feet, equal to 8.1 squares. The cause of this dike and Cross-dike No. 4 being damaged to such an extent is most likely to be traced to weakness in construction, the bar end of both dikes having been driven before the standard dike was introduced; all other dikes being incomplete, Cross-dike No. 5 was overstrained.

The water was dammed to a height of from 14 to 18 inches at the first line of piling. Not being able to withstand this excessive strain, the braces, which were 40 feet long, equal to the depth of water in the channel, gave way. To prevent like injury shorter braces are used, the necessary width of dike being obtained by increasing the number of rows of piling. The rocking motion which was observed at the widest portions of Cross-dikes Nos. 4 and 5 will be diminished by using shorter braces. Although Cross-dike No. 5 was severely damaged during the high water, a large and high bar was deposited below it; and where the tipped grillage remained uninjured the crest of the bar is 25 feet above low water of 1879. The curve of low water represented on sketch by dotted lines, from April survey, closes below this dike, a deposit of 12 feet having taken place since October, 1883.

Work constructed since November 1, 1883, is represented on sketch by dotted lines.

Very respectfully, your obedient servant,

GEO. W. GEUDER,
United States Assistant Engineer.

A. J. FRITH,
Assistant Engineer.

F 3.

REPORT OF WILLIAM A. GOULD, ASSISTANT ENGINEER, UPON OPERATIONS OF THE MATTRESS AND REVETMENT PARTY FROM FLETCHER'S FIELD TO ELMOT LANDING.

MILL BAYOU, ARK., *October* 1, 1884.

SIR: In pursuance of orders from you I have the honor to report the operations of the mattress and revetment party under my charge, subsisting on Q. B. No. 12, since the beginning of this season's work in May (Appendix F 2 and Plate X.)

The work has been confined to the protection of the river bank below low water from caving. The location of the works is on the Arkansas shore, beginning at a point below Mill Bayou called Fletcher's Field, and the work contemplated extending to Elmot Landing, a distance of 3 miles of concave bank. Work was begun on May 26 just below Elmot Landing, 400 feet above Range "37 A," by building and sinking a woven willow mat, of 78 feet in width and 800 feet in length, where the bank had been attacked by underground seepage, and extensive caving had been operating for several weeks on a bank some 20 feet high. This caving was apparently arrested from extending further down river by a collection of heavy willow stumps, which still retain the top of the bank. This mattress was built on mattress barge and launched off in successive lengths until 804 running feet were completed. Part of the brush was very old, being a remnant of brush on hand at the close of last season's work; the poles were large and heavy cottonwood. Two wire cables, ¾ inch, were used on the head and four in the body of the mat, to retain it in position while building, and about 15 per cent. of them expended in sinking. One hundred and twenty-five and nine-tenths cords of new brush, 24 cords of new poles, 37 coils of wire, and 566 cubic yards of stone were expended in constructing and sinking. The mat contained 627 squares, and the cost, including labor, cooks, and waiters, was $389.33. Work began on May 26, and completed June 2, being seven days.

On the 11th day of September hydraulic Grader No. 2 began operations at this point. The strata of the bank for the 6 feet next above the water were composed of sand, which in many cases, where the toe of the slope was protected by the upper edge of the sunken foot-mat, maintained its position and retained its proper slope, while in some portions of the grade large cavities were formed, which will require dressing with shovels.

The operations of the grader covered a period of 7½ days, all machinery working in perfect order. Seven hundred and fifty feet of bank was graded from September 11 to 18, being 7½ days.

The working force consists of foreman, 2 engineers, 2 firemen, 7 men at the discharge, 1 linesman, 1 deck hand, 1 cook, 1 waiter, and 1 night-watchman; total, 17. The cost of this grade for labor was $213.33. The cost of grading per yard was 2 cents.

The extension of the Gold Dust main dike last season to protect the head of Elmot Tow-head, thereby turning the flow of the water from the Tennessee shore, rendered necessary the protecting of the opposite bank of the river on the Arkansas shore by foot-mat and revetment, &c.

On the 3d day of June the plant under my charge was towed up river to a point near Mill Bayou, on the Arkansas shore, 540 feet above Range "31 A." A foot-mat ordered to be constructed 175 feet in width. It was deemed impracticable to construct and maintain the head of this mat at full width. A boom 90 feet long was constructed to form a head-piece, and at each launch the width of the mat was increased, until in 200 feet the full width of the 175 feet was obtained, and afterwards maintained. This increased width was at first obtained by covering more "way poles" on the barge at each launch, but this left square recesses in the sloping edge of the mat, which were imperfect in construction, and served to accumulate and retain floating drift, and a change was made, making the outer pole continuous and maintaining the proper slope, the widening poles uniting where their position was intersected by the outer pole.

Some of the head cables were passed under the boom and made fast in the mat some 40 feet in rear to prevent the head of the mat from "diving" as any strain on the cables tended to raise the boom out of water by the cable trying to maintain a uniform degree of elevation. Five wire cables were used longitudinally, the outer edge of the mat being strengthened the most. This mat was built 2,010 feet long and 175 feet wide=3,426 squares. The material used in its construction was 1,741.41 cords of brush, 198.70 cords of poles, 91¾ coils of wire, and the cost of building this 2,010 feet was $1,751.91.

On June 30, the water being 58 feet deep on the outer edge, some 1,500 feet of this mat was sunk, with 1,369¼ cubic yards of stone, the remainder during the night sunk by the force of the current, and being attached to the mat-barge at the lower end it tore loose just where the mat was ballasted to the river bottom, and was lost.

On August 2 Grader No. 2 began work at the head of this mat, and worked until

August 16, being 13 days. During this time 1,140 running feet of bank was graded and 11,030 cubic yards of earth were removed, at a cost of about 2 cents per yard: 1,019 feet of revetment was placed (average width 87 feet) on this graded slope, and ballasted with stone for the first 10 feet above the water; that is, from 5 to 12 feet on the gauge, the remainder being left for higher water. The subsequent falling of the river showed that cavities under the inner edge of the foot-mat were completely filled by the action of the grader.

On July 1, while waiting for stone to sink Mat No. 1, a second was begun about a mile down river, immediately below the large drift rack, 750 feet above range "34 A." This mat was of similar construction to Mat No. 1. It was started 120 feet wide on the head and widened to 175 feet. This mat was 1,750 feet long, and contained 3,358.70 squares; was constructed of 1,417.75 cords of brush, 149¼ cords of poles, 86¼ coils of wire, and the labor expense due to the mat was $2,043.86. It was sunk down-stream in 70 feet of water by using 1,757¼ yards of stone. On the 18th of August the grader began work here, and removed 22,198 yards of earth, at a cost of 2.3 cents per yard, leaving a slope of 3 to 1.

This bank had been caving and leaving several large pockets, which were increased in size by the grader. In three of the pockets three thick submats were constructed, covering the sunken ground, and being only secured at their upper edge, the remaining portion being well ballasted, was free to sink and follow down any future caving beneath them, while the revetment mat proper was built continuous above them without connection. These mats were about 70 feet wide and about 150 feet long; they contained 323 squares, 180 cords of brush, 63 cords of poles, and 240 yards of stone. The graded slope at this mat is being covered with revetment and will be completed during the month of October.

On the 4th of August Mat No. 3 was begun 928 feet below range "31 A," and was started to overlap 100 feet of the broken edge of Mat No. 1. A projecting point of the bank rendered the starting of a mat here difficult work, owing to the force of the current. The first and second attempts at starting proved unsuccessful, owing to the breaking of the boom and the parting of head lines. Some 90 feet of mat was destroyed, and the mat boat required repairing. By mooring an empty coal-shell above the head of the mat, to check the force of the top current, and using short head lines to the boom, the third attempt was successful, and 1,713 running feet of mat 175 feet wide was completed; its further extension was stopped by the half mile of drift rack in the river bed below. This mat contained 1,982 cords of brush, 210 cords of poles, 111 coils of wire, and after remaining afloat for 30 days was successfully sunk on September 26, with 1,696 yards of stone, in 45 feet of water, or 42 feet below low-water line. The channel was only 150 feet from the shore, leaving the outer edge of the mat 3 feet higher than the center.

A summary of the work to October 1 will show 4,931 running feet of wide foot-mat, also 800 feet of narrow mat, sunk for low-water protection; 2,000 feet of revetment, partly loaded, and a reasonable prospect that the grader will prepare 2,000 feet of bank for revetment, and that all foot-mat sunk will have its corresponding revetment built and ballasted before any serious rise of the river. An experiment was tried to drive a line of piles in front of a caving bank, and by driving into the deep clay strata and walling on the shore side with willow fascines to check the caving, but the action of the caving was so rapid that before the piles could be secured some were scoured out for lack of a foot-mat, and the experiment was postponed.

It has been difficult to work a full force at any time, owing to the uncertainty of material from the contractor, and the cost of the mat has been largely increased thereby.

Very respectfully, your obedient servant,

WM. A. GOULD,
United States Assistant Engineer.

A. J. FRITH,
United States Assistant Engineer.

F 4.

REPORT OF W. L. SEDDON, ASSISTANT ENGINEER, UPON OPERATIONS AT OSCEOLA UPPER AND LOWER BARS.

OSCEOLA LOWER BAR, *October* 11, 1884.

SIR: I have the honor to submit the following report on the progress and condition of the work at Osceola Upper and Lower Bars for the period from November 1, 1883, to October 1, 1884. During the period work at this point was entirely suspended from January 4 to June 15, and from June 25 to August 14. The work done has consisted

in strengthening Cross-dikes Nos. 1 and 2 with cable bracing, in repairing breaks in Cross-dike No. 3, and in continuing the protection of Osceola Lower Bar with mattress and revetment.

Following the divisions of the work made in the report for 1883, I shall take each under consideration—first, as to work done, and second, as to condition and results.

OSCEOLA UPPER DIKE.

No work has been done on this dike, it having been abandoned on the commencement of Cross-dike No. 1, as stated in report for 1883.

The partial destruction of the dike, which had taken place the previous year, was nearly completed by the high water of 1884, and there now remains standing only about 1,000 feet near the Arkansas shore. This result was to have been expected from the weakness of the structure, cited in the last report. As far as can be ascertained, the 100-foot mattress, previously placed along the dike, remains in good condition.

In considering the results from this dike some difficulty is experienced, as a large portion of the fill which has taken place along its former line should be attributed to Cross-dike No. 1; though that behind the portion still standing has undoubtedly been increased by the action of this work.

OSCEOLA CROSS-DIKE NO. 1.

This dike was strengthened with wire cables, in November, 1883; since which time no further work has been done on it.

The condition of the dike is good, and its action during the high water of 1884 was entirely satisfactory. The structure withstood the strains brought upon it by the large accumulation of drift, without any appreciable damage. In front of the dike, the drift, while it has decreased somewhat in area, a portion of it being freed by the breaking of the lower end of the upper dike, has apparently increased in mass. So much of this drift is now partially imbedded in the bottom, and the whole mass is so closely packed together as to form a raft which would, I think, insure the closing of the chute, even if the dike were removed. The fill in front of the dike has been very marked, and the low-water shore-line now extends beyond the line of the upper dike, as shown in the accompanying sketch (Plate XII). Behind the dike the fill has been extremely large. At its lowest point the chute here is dry at a 10-foot stage of the river; while for about two-thirds of the way across, the fill lacks only a few feet of being as high as the adjacent tow-head, and is covered with a thick growth of young willows from 2 to 4 feet in height.

One noticeable feature about this fill, is, that it is composed almost entirely of silt, which shows how completely the current has been checked by the action of the dike. This character of fill, extending as it does far down the chute, and even beyond Cross-dike No. 2, shows also, I think, the area over which the influence of Cross-dike No. 1 extends, and should be attributed to it. Judged by the above condition and results Osceola Cross-dike No. 1 may certainly be considered as an eminently successful piece of work.

OSCEOLA CROSS-DIKE NO. 2.

This dike was also strengthened with wire cables in November, 1883; which has been the only work done upon it within the period.

But little change has taken place in the condition of the structure since last report. Neither the eastern nor western sections sustained any noticeable damage from the high water of 1884. The condition of the dike is therefore fair, though the western section has begun to show signs of weakness, apparently more from the action of time upon the perishable material of which it is constructed, than from any other cause. A considerable fill has taken place behind this dike, beside that mentioned as properly attributable to Cross-dike No. 1; the results produced by this dike may therefore be considered as fairly satisfactory.

OSCEOLA MIDDLE DIKE.

No work has been done here during the period. The condition of the dike is bad. As in the case of the upper dike, its previous partial destruction was nearly completed by the high water of 1884. Breakage by drift and bottom scour have combined in producing this result. About 600 feet of dike, in a badly broken condition, still remains standing near the foot of the upper bar. Of the 100-foot mattress sunk along the front of this dike, nothing definite can be said; but judging by the scour which has taken place here it is most probable that at least a portion of it has gone out.

OSCEOLA CROSS-DIKE NO. 3.

The work at this dike, with the exception of the addition of 3,418 square feet of wattling and the sinking of 200 linear feet of foot-mat, previously constructed, has consisted in the repairs of breaks which have taken place in the structure.

On the 14th of November the 200 feet of the dike, which consisted in a row of clusters with inclined braces, began to show signs of weakness, caused principally by bottom scour. Preparations were at once made for strengthening this portion of the dike, but before anything could be done the entire line of clusters gave way, and at the same time a break of 150 feet took place in the front line of the dike proper. The work of repairing this break was commenced on December 2. The repairs consisted in the strengthening of that portion of the dike where the front row was broken, with two rows of piling driven behind and connected with braces to the old dike, and in the driving at the gap of a V-shaped connection of three-row dike, as shown in the sketch. These repairs necessitated the driving of 150 of two and 375 feet of three row dike, all of which was completed by the 15th of December. As soon as the driving was completed the work of making a grillage foot-mat along this new portion was commenced; 419 linear feet, equaling 20,705 square feet of this work, was made and sunk by January 4. On this date all further work had to be abandoned on account of the high water, thus leaving about 100 feet of the dike in an unprotected condition.

An inspection of this work after the high water showed that at the eastern end the water had undermined the revetment, and that the bar had caved back some 50 feet, while about 100 feet of the dike had also scoured out, making a total gap of 150 feet at this end. It was also found that the drift had broken about 100 feet of the dike at the Arkansas end. The repairs of these two breaks were commenced on June 15 and completed by the 25th of the same month, 150 feet and 120 feet of the two-row dike being driven at the bar and Arkansas ends respectively.

The condition of this dike is now good, and its action during the high water of 1884 was very satisfactory, considering the nature of some of the older portions of the structure, for the only damage sustained was that of the two small breaks mentioned above, though the accumulation of drift in front of it was even larger than that at Cross-dike No. 1. This accumulation of drift now amounts to more than thirty acres, and is very closely packed together. The fill in front of the dike has been large, while that behind it has been very marked. From its action and results Cross-dike No. 3 may therefore be also classed as a successful dike.

OSCEOLA DIKES.

Now considering these dikes together, as members of one system, the object of which is the closure of Osceola Chute, their action during the past year has been very satisfactory. A comparison of the fill and scour, which has taken place through the influence of these dikes, from November, 1883, to June, 1884, showed a very large excess of fill. Indeed, with the exception of a small area just behind the middle dike, there has been almost no scour, while the fill has varied from one to twenty feet in height. Therefore, viewed from this standpoint and by these results, the Osceola dikes may, as a whole, be considered as a successful piece of work.

OSCEOLA UPPER BAR.

No work has been done at this point during the period.

The condition of the mattress and revetment previously put in is only fair. The erosion of the bank at the lower end of the bar, where no revetment had been placed, continues, and the water is gradually undermining the revetted portion above. As far as can be ascertained the shore-line of the lower half of the bar has moved back about 100 feet during the period.

OSCEOLA LOWER BAR.

The work at this point from November 1 to December 26 was confined to the sinking of the section of mattress made prior to that time. The long delay in getting stone for this purpose, and the consequent accumulation of drift near the head and along the outer edge of the mattress, made this work very difficult and necessitated the strengthening of the whole section. This strengthening was accomplished by the weaving of wire cables through and the wiring of longitudinal poles on top of the mattress. After this had been done no further difficulty was experienced, and the section of 2,663 linear feet, equaling 406,000 square feet, was successfully sunk by December 26.

On August 14 preparations were begun for resuming work at this place. An examination showed that the head of the bar for a distance of about 1,000 feet had cut back from the old mattress so far as to necessitate the putting in of a new section at this point. A 150-foot mattress for this purpose was commenced at the head of the bar on August 18, and was carried down to the point at which the old mattress still joined the shore. This section, containing 1,337 linear feet, equaling 222,481 square feet, was completed and successfully sunk by September 17.

On September 6 the grading of the bank for revetment was commenced. The work was done with shovels at those points where the grade was already approximate and with hydraulic Grader No. 2 where the bank was steep. By October 1 the grading was completed from the present head of the bar to the end of the mattress thus far constructed, a distance of 3,056 feet. Of this amount 1,636 linear feet was graded with shovels and 1,420 linear feet with hydraulic grader. The minimum slope allowed has been 2½ to 1, which at places has been increased to 3½ to 1.

The grading has been followed up with the revetment as fast as material could be obtained for the purpose, and by October 1,972 linear feet, equaling 61,640 square feet, has been made.

The condition of the mattress previously put in at this point is good, and that portion of it sunk during November, 1883, has served well as a partial protection to the bank.

The above report, together with a sketch showing the present condition of the work and containing a table with full dimensions of all work done during the period, is (Appendix F and Plate XII) respectfully submitted by—

Your obedient servant,

W. L. SEDDON,
Assistant Engineer.

MR. A. J. FRITH,
United States Assistant Engineer in charge.

Work done from November 1, 1883, *to October* 1, 1884.

Kind of work.	Linear feet.	Square feet.	Remarks.
Dike, 2 rows	430		Repairs of Cross-dike No. 1.
Dike, 3 rows	375		Do.
Foot-mat	419	20,705	Do.
Foot-mat, sunk	619	33,305	200 feet made previously.
Wattling		3,418	Cross-d. No. 3.
Mattress	1,337	222,481	Osceola lower bar.
Mattress, sunk	4,000	629,081	2,663 feet made previously.
Revetment	972	61,640	Osceola lower bar.
Bank graded	3,056		Do.

F 5.

REPORT OF JAMES M. RILEY, SUPERINTENDENT, UPON OPERATIONS AT OSCEOLA CROSS-DIKE NO. 4.

GOLD DUST, TENN., *October* 1, 1884.

SIR: I have the honor to present the following report (Appendix F 5 and Plate XI), which concerns the building of Osceola Cross-dike No. 4, constructed during the term for which this report is made, November 1, 1883, to October 1, 1884.

Work was begun May 12, 1884, and forces withdrawn August 5. Without, however, completing the design, 400 feet of second row and 600 feet third remain to be added to the first row. This can be done at 25-foot stage. Falling river did not allow the finishing of this portion, which is on the crest of the bar and midway of the line of dike. It may be as well to say the absence of these rows can in no way affect the integrity of the structure. They can b · thrown across so rapidly when the river rises as to cause no apprehension from not being in place.

The line of this cross-dike for the most part is parallel to, and 100 feet above, Range 48½; its length, 2,450 feet, inclosed at either extremity by Osceola-Bullerton main dike and the Arkansas shore.

The object in placing this dike where located was the closure of Osceola Chute, and in this to deflect the body of water entering between the upper end of Osceola-Bullerton main dike and the foot of Osceola Bar, along the outside of the main dike.

This result was to be expected from the action of other cross-dikes, built to attain similar results under almost identical conditions. Osceola Cross dikes Nos. 1 and 3 will occur to you as fair examples.

It was deemed necessary to conduct the work with the utmost celerity. Instructions were to this effect. It was well known that the slope of the river toward the Arkansas shore, along this portion of the reach, increased rapidly, with decreasing stages of the river.

The bar to be protected from erosion extended westerly from the main dike, three-fourths of the length of the dike to be built. Its height varied from 0 to 20 feet above low water of 1879. The material was fine sand, left by the high water just passing. This would be easily swept away if not protected, giving the river full sway, in an old channel, and so on down through Bullerton Chute. What will be referred to as channel, from the bar inward to Arkansas shore, will be contra to what is termed bar. Already this channel had a width of 600 and depth of 30 feet, 4 feet below low water of 1879; gauge reading, May 12, 26 feet. The current was developing. The water impinging on the Arkansas shore, at an angle of 45°, caused the bank to cut rapidly from range 48½ to range 49.

Soundings revealed scours in excess of the fall in the river, and continued; the gauge marked 13 feet on June the 6th. About this time the 10-foot curve connected through the chute. From June 6 to 20 a rise of 4.50 feet was noted. Then an almost steady fall until the end of July of 6 feet, and, with the exception of a few oscillations, continued until latter part of September, when the gauge was 3.15 feet, the lowest reading. Instructions were received May 10 from you to construct what is known as the standard dike, to be built to high-water mark. This was done in all essential features. At times when exigencies arose the type would be departed from, and at your instance changes would be made looking to the further strengthening of the dike, principally by the use of more timber and wire cables. The mattress work did not follow so closely the method proposed, in that flat grillage was substituted for tipped grillage, no piles being used. What has been termed swinging mattresses were directed to be sunk previous to driving the dike across the channel. The dike as built is as follows: Across the bar from the main dike 1,700 feet, except part mentioned as incomplete, consists of three rows, placed 20 feet apart, of single piles, bents spaced 12 feet. For the remainder, 850 feet, the number of rows increased with the depth of water, the maximum being six rows, 160 feet width of dike in 50 feet of water.

Nothing arbitrary can be said as to the number of piles used in clusters of the different rows; but say from two to six piles, without reference as to the line occupied. About 200 feet from the Arkansas shore the line of the dike was advanced 100 feet, so that the rear line joins the front line and connects at an angle with the line as originally, 500 feet distant, near the bar.

Before the dike was driven eight swinging mattresses were sunk across the channel. These were held in position by mooring clusters while being placed on the bottom. These mattresses were of varying size, 110 by 30 feet to 110 by 85 feet, overlapping 15 feet. The down-stream side, when in position, was just below the front line of the dike, so that the grillage mattress afterward sunk rested on top.

Grillage mattresses extend the length of the dike, heavily loaded with rock The width changes—least, 50 feet; greatest, 125 feet. An examination of this cross-dike was made a few days ago at your request, you accompanying the party in the sounding skiff

It was found the drift extended almost to the foot of Osceola Bar. The dike showed no signs of weakening. Soundings in between the rows of the dike, across the channel, show a fill in some places of over 20 feet; in no place less than 5 feet. Behind the dike, 100 feet, the fill was shown to be 15 feet. No scour or tendency could be discovered. These comparisons are made between the greatest depths found in July, and represent the action of the dike during two months. During inspection the maximum depth found was 31 feet, 200 feet out from the Arkansas shore. This place during construction proved more troublesome than any other, registering then 50 feet.

Reducing soundings, the fill at this point is about 6 feet. Below the dike 100 feet, in July 43 feet, in September 17 feet, were the greatest depths, indicating a fill of 13 feet.

Before finally submitting my report some details as to construction will be given. The first trial of swinging mattresses was had at this dike. While experience has since shown the full benefit of the scheme was not derived, their absence would have been severely felt. Had it been feasible to have built them of such a width that all the rows of the dike could have been driven through, the perfection of the idea, greater security, would have been had in closing he opening.

The method adopted to place the sills was to drive clusters, 3 to 8 piles, 100 feet above the dike; spaces between clusters varying from 15 to 75 feet; number of piles in clusters and number of feet spacing increased with the depth of water and velocity of current, or as midchannel was approached.

The flow of the current being from 9 to 10 miles per hour, estimated, and depth of

rater 38 feet, with drift in large quantities entering above, must account for peculiar isposition of clusters. Trial was made to drive these at uniform distances, so that hey not only would be useful in manipulating the mattress boats and pile-drivers, ut serve as a drift-row. The change to wider spaces was because as a temporary drift-ow they were too great a success, holding the mass a day or so, then giving way, etting the collected wrack-heap down in body upon the works below.

To hold the pile-driver in place, a 2-inch (diameter) line was run from a clump of iles on the inside of the foot of Osceola Bar, distant about 1,800 feet. With the aid f bow anchor on one side and lines to the Arkansas shore, the driver was held reason-bly steady. Easily movable ballast was provided in shape of coils of wire. Some lusters were redriven eight times. Two 100-feet mattress boats were provided. It ras thought by using both at the same time, end to end, a mattress over 200 feet long ould be made, thus gaining time.

The plan followed was to construct a launch on the boats while at shore, in readi-ess to be moved to the line, which was always done in the morning. After getting nto position behind the clusters, ways pointing up-stream, cables, which had been astened to the piles when driven, whose one end was attached firmly to the pile near he bottom of the river, the other spiked to the top of the pile, were taken off and assed through the mattress. When all was secure a launch made, and as many more s possible during the day. In no case was it thought best to leave a mattress afloat luring the night, nor was it done. In every instance the sections were sunk the ame day that they were made. Mattress boat taken to the bank, out of the way f the drift, sinking commenced on the lower inside corner, a partially loaded arge of stone placed over this corner. Enough stone was thrown on the mattress o allow the barge to float over it. By repassing all was loaded evenly. Marline at-ached to different parts of the mattress determined its position at any time. The ndeavor was to force the mattress to remain horizontal in going down, to present no olds until near the bottom, then suddenly sink it to its place. This plan worked rell. But one section swerved from its position, and this one because the outer clus-er of piles pulled out, but being nearly down was quickly sunk without loss, the re-naining cluster holding one-half of it without breaking the mattress. In driving iles pile-driver No. 14, 36 feet leads, frequently handled piles over 80 feet long. She eing of lighter draught than those with 46 feet leads, was always placed in swiftest rater. The penetration of piles was never less than 20 feet in the channel portion f the dike; were driven without being sharpened.

The mattress party followed the drivers closely, sometimes making grillage mat-ress by hanging to second row while rear rows were being driven, then connecting hrough or sinking at once if needed, afterward lapping through with another mat-ress.

The losses met with were all on account of the lodgment of drift and rafts upon unfin-shed work. What would equal 400 feet of 3-row dike was carried away during con-truction; also a section of foot mattress 225 by 110 feet. This is about the total of nishaps, but occurring at different times set the work back greatly.

Delays were frequent, from unavoidable causes.

Respectfully submitted.

JAMES M. RILEY,
United States Superintendent.

A. J. FRITH,
United States Assistant Engineer.

F 6.

REPORT OF AUG. J. NOLTY, SUPERINTENDENT, UPON OPERATIONS AT BULLERTON TOW-HEAD AND OSCEOLA-BULLERTON CHUTE.

SIR: I have the honor to herewith submit my report of operations at Bullerton Tow-ead and in Osceola-Bullerton Chute for the period included between November 1, 883, and September 30, 1884.

On November 1, 1883, there remained to be constructed at Bullerton Tow-head 500 eet of foot mattress, 2,700 feet of bank revetment, 600 feet of bank to be graded, and large amount of bank revetment to be loaded with stone.

The amount of foot mattress to be made had to be augmented by 700 linear feet of 0 feet wide, as the river had risen so much that proper connection between low-water ank protection already sunk, and high-water bank protection yet to be constructed ould not be made. Hence, this narrow mattress, which should be really considered s so much bank revetment, was constructed and sunk inside of main foot mattress.

At this time both the supply of brush and of stone was very scanty, and it was determined to only finish the high-water bank protection half way up the bank, leaving an upper zone 30 feet wide entirely unprotected.

However, before the water had risen high enough to greatly interfere with the work there was an increase in the supply of material and the work was completed. The loading of revetment could not be entirely finished owing to the rapid rise in the river, and the stone was dumped in piles on the work, the intention being that as the water fell it would be more evenly distributed.

In the early part of January the river began rising rapidly, with much ice running. As the work on Bullerton Tow-head was completed as far as could be done, orders were received from headquarters to find a suitable and safe place for laying up part of the fleet during the flood season. A very safe harbor was found between the tow-head and Arkansas bank, and the work of moving the fleet was at once begun, and continued from day to day until completed. A small force was kept employed during the month securing the work on the outside bank of the tow-head, which they managed to do before the river flooded its bank.

From the latter part of January until the end of May no work except such necessary for the proper care and preservation of public property, and for which a small number of men were retained, was done. By the latter part of May the river had fallen so as to expose about 7 feet of bank, and an examination of the outside of Bullerton Tow-head revealed damage to the work there. A close inspection showed that the damage was caused by seepage from the interior. The action of this seepage water was to soften and slowly wash out the stratum of sand and silt overlying the clay stratum, allowing the upper strata to settle down, and the work to slide into the water.

Operations were at once begun at these places and continued from the 1st of June until the 5th of July, by which date all the damage had been repaired. This work involved the construction of 1,391 linear feet of mattress from 45 to 50 feet wide, 1,105 linear feet of revetment, and 1,004 linear feet of grading. The mattresses were made in the following manner: A mattress barge capable of constructing a mattress 165 feet wide was brought alongside of the bank, and with its long axis parallel to it and sparred out 25 feet. A grillage of stout poles was then constructed, one edge of it resting on the bank, the other on the upper terminus of the ways of the barge. Upon this grillage a heavy mattress was constructed, and when finished the barge was sparred out from underneath it, the mattress being first fastened to the top of the bank by wire cables in such a manner that it could neither move outstream nor downstream, nor could it slide down the bank after being sunk.

Each successive mattress overlapped the preceding one sufficiently to make continuous work. The bank was then graded to a slope of 1 on 3 and the revetment laid thereon. It was supposed that the mattress just described would prevent the oozing out of the semi-liquid sand and silt, and that by grading the bank to a long slope and thus removing much of the superincumbent weight, the tendency to settle down and slide out would be much lessened. The work of repairing was finished on the 5th of July, and at that time the bank presented a fine appearance, all the new work having been uniformly loaded with stone and the older work being covered down to the water-line with a heavy growth of willows.

On the 5th of July the work of closing the chute behind Bullerton Tow-head was begun by commencing the driving of a line of anchor piles across, 150 feet above the line of proposed dike. These piles were driven in clusters of three each, and from 25 to 50 feet apart, the wider spacings being in shallow water. To each pile a wire cable was fastened at such a distance from its foot that when the pile was driven the cable would have entered a few feet into the bottom.

At the same time the construction of footing mattresses at each end of proposed dike was begun, that along the tow-head bank, where no caving was going on, being 200 feet long, while that at the opposite bank, which was a bluff and caving one, was 552 feet. After these mattresses had been sunk the bank above them was graded and high-water bank protection laid thereon.

The object of thus protecting the banks was to prevent caving and cutting around the ends of the finished dike.

As soon as a sufficient number of anchor clusters had been driven, the construction of dike foot-mattresses was begun. These were made 165 feet long each, and varied in width from 75 feet to 100 feet, the wider ones being sunk at such places where the depth of water required the dike to consist of four rows of piling. These mattresses were anchored with cables to the anchor clusters above mentioned and in such a manner that when sunk from 25 to 30 feet of the mattress would be above the first row of dike, while the entire width was such that all the piles of the different rows penetrated it, each mattress overlapping the preceding one, so that there really was a continuous mattress across the line of dike.

By reference to the sketch accompanying this report (Plate XIV), it will be seen that this dike, which is designated Bullerton Dike No. 2, is nearly completed.

The gap cannot be closed until the upper work is done, as the towing of material is one through it.

As fast as this dike was completed a party followed with the construction of an inlined grillage mattress between the former. The grillage for this work is built upon iles, which latter are so hung with wire cables from the riders that when the mat s sunk the whole will make an angle of 30° with the horizontal, the up-stream ends f piles and edge of mat resting on bottom. Nine hundred and forty-five feet of this rork was completed at the end of the period covered by this report, but only about 00 feet sunk, as it was feared that the sinking of more of it might so increase the elocity of the already strong current running through the gap as to seriously increase he difficulty of towing through it.

On September 3 work on Bullerton Dike No. 1 was begun. This dike is a continuation of the section completed the year previous, which, excepting 100 feet of the xtreme end, is yet in good condition. Here only the Arkansas bank required any rotection, and high and low water bank protection 276 feet long was constructed.

In other respects the work was done as at No. 2; that is, the entire length of dike vas first mattressed and the piles driven through the mattress.

In this dike, also, a gap will have to be left until the work on the one at the foot f Osceola Chute has been completed. This latter work consists in strengthing about 50 feet of the previously-constructed dike, and was begun on the date terminating his report.

It has been found that the method of constructing dikes as practiced here, *i. e.*, first aying foot-mattress and then driving the piles through it, is decidedly the safest lan where the work is subject to scour, and much to be preferred to that where the like is first constructed, and then a grillage mat built between the piles and sunk. n the former case there is very little trouble from drift getting under the mattress, s the anchor clusters will collect and hold it until the mattress is sunk, and, should ny get under it, it will usually work out during the operation of sinking.

When these mattresses are sunk it is quite certain that they lie in good shape on he bottom. In the other case, the drift collecting against the dike, and projecting nore or less inside of it, is a serious obstacle to properly sinking the mattress, and, hen, where piles are driven in clusters of two or more, as is usual, and where they re more or less spread at bottom, it is impossible to sink it so that it will lie flat.

No difficulty has been encountered in sinking the dike foot-matresses. One of them, 60 by 100 feet, was lost before it could be sunk by the accumulated drift breaking lown the anchor piles to which this mattress was fastened.

This has been the only loss incurred at this work, not a pile driven having been coured out or otherwise lost.

The maximum depth of water on the line of Dike No. 1 was found to be 28 feet, and t Dike No. 2, 34 feet. An examination of the outside bank of Bullerton Tow-head nade in the early part of August, revealed damages to the work there at four places, wo of which were at the site of previous repairs.

The damage is not very extensive and has not increased in extent since first discovred. At one of these places the damage is evidently caused by failure of the high nd low water bank protection to properly connect.

This could not be avoided at the time, as after the foot-mattress had been sunk and efore the revetment could be laid the water rose considerably.

As it appears evident that the usual method of protecting the banks from erosion rill not avail against interior seepage, some other plan will be tried when the repairs re begun.

A series of experiments to determine the best method of counteracting the damage aused to river banks by seepage water has been conducted here with an apparatus esigned by Mr. A. J. Frith, assistant engineer in charge. Twenty four experiments rere tried, some of them covering a period of eight days. From these it would appear that a system of lateral and transverse blind drains bedded on the clay stratum rill drain these places without injuring the banks. Whether these drains would not n time become choked with the mud to such an extent as to become inoperative can nly be decided by tests, covering a long period, in the natural banks. Very favorble results were obtained by driving piles at the foot of the bank, and then filling he space included between the lines of piling and the bank with fascines heavily reighted.

In practice there would be two rows of close piling, one to be driven about equilistant between the foot of bank and the water-line, the other at the foot. The paces between the first row and the bank, and that between the two rows of piling o be filled in with thick, narrow mattress, and the whole heavily loaded with stone. This work will not extend above water surface, the bank above to be graded and reveted in the usual manner. It is believed that this method will prevent the sliding out of the softened silt and sand composing the bank, while at the same time allowng the seepage water to drain through. It acted thus in the experiments, and will

be tried on the Bullerton bank. The drainage plan will also be practically tested there.

Appended is a summary of work done during the period, and a statement of material expended in construction during the same time. Necessarily, there was a large amount of work done which cannot be properly tabulated, such as removing drift, clearing of banks, removing stone and *débris* from damaged parts of bank, pumping out boats, and other work necessary for the proper care of plant.

The accompanying sketch (Plate XIV) shows the condition of the work at Bullerton Tow-head and in Bullerton Chute on September 30, 1884.

To avoid confusion of lines, the foot-mattress is shown in front of dikes and the inclined one in the rear.

The heavily shading sections of Bullerton bank show location of damaged parts.

Respectfully submitted.

AUG. J. NOLTY,
United States Superintendent.

MR. ARTHUR J. FRITH,
United States Assistant Engineer in charge.

Summary of work done from November 1, 1883, *to September* 30, 1884.

Work done.	Bullerton Tow-head.	Bullerton Chute.	Total.
Foot-mattress made ....squares..	1,242.85	3,393.7	4,636.55
Foot-mattress sunk ....do...	1,422.85	2,983.7	4,406.55
Revetment made........do....	2,636.2	1,039.21	3,675.41
Revetment loaded ....do....	6,186.9	856.11	7,043.01
Inclined mattress made........do....	....	647.9	647.9
Inclined mattress sunk ....do....	....	275	275
Dike finished........linear feet..	....	1,226	1,226
Grading bank ....cubic yards..	13,327	10,371	23,698

Summary of material expended from November 1, 1883, *to September* 30, 1884.

Material.	Bullerton Tow-head.	Bullerton Chute.	Total.
Stone........cubic yards..	13,049.7	3,245.8	16,295.5
Brush........cords..	2,737.9	3,021.37	5,759.27
Poles ....do....	139.5	423.25	562.75
Piling ....feet..	....	97,321	97,321
Wire........pounds..	8,500	11,000	19,500
Spikes ....do....	350	2,903	3,253
Coal ....bushels..	160	1,883	2,043
Rope ....feet..	....	1,825	1,825
Wire cables ....number..	200	3,812	4,012

F 7.

REPORT OF S. P. HATFIELD, ASSISTANT ENGINEER, UPON OPERATIONS AT PLUM POINT DIKES.

PLUM POINT DIKES, *October* 11, 1884.

SIR: In obedience to instructions received from you, I have the honor to submit the following report of operations at Plum Point Dikes, covering the period from December 1, 1883, to October 1, 1884.

From December 1, 1883, to December 4, only a small piece of foot-mat was made at the head of the main dike, and work was suspended.

To this time there had been built—

	Feet.
Main dike........	2,008
Cross-dike No. 1........	794
Cross-dike No. 2........	643
Total........	3,445

March 10 work was resumed with a force of four pile-drivers in charge of Mr. James Anthony, fleet foreman. April 10 I was directed by you to take charge.

The dikes were commenced at a 28-foot stage of water, and kept high near the shore, gradually falling to about 17 feet. The dimensions of the dikes are, width equal twice the height, and up to 25 feet high two piles in front row; above this height 3 piles in front, and 2 piles in the other rows.

When the width of the dike would be over 22 or 23 feet between the rows, 4 rows of piles are intended, as braces longer than this too readily break. Cables lead to the rider of the rear row from the river bottom at front and middle rows; these cables are fastened to the piles before driving. Diagonal braces of cable are stretched from every fourth pile in each row over the top of the dike, and to prevent vibration of the piles in "clumps" of 2 and 3 of front row, they are being wrapped with cables at nearly middle height.

This is found to stiffen the clump. Each pile is lashed to a brace and each brace is fastened with one turn of cable around the pile, and two turns around the rider—braces being notched to prevent slipping, and the lashing so disposed as to meet the pressure. The old method of fastening by drift-bolts and separate strands of wire which were drawn tight by twisting, was abandoned, and cables of various lengths required have been supplied. Experiments made May 7 showed that the cables required for security of the end fastening, at least one and one-half turns with three spikes turned over the cable and clinched into the wood—this rule has been followed in all fastenings.

The pile-drivers lashed the riders to the piles, but the braces were lashed by a "wiring party." This party was organized under a careful foreman, with a view of securing more uniform and thorough work than would have been done by the drivers, whose foremen were apt to be in too much haste to be careful. The foreman of the wiring party also superintends all cable work which requires steam-power of the drivers. In addition I will state, that the orders have been that the piles should be driven at least 16 feet, but near the outer end of the dikes they have been driven 20 feet to allow for some scour. Cross-dike No. 6 was commenced during high-water and about 400 feet built; the strong current here soon scoured the bottom so that about 200 feet of the dike fell in. The wreck, remaining in deep water, proved difficult to clear away, and the dike was rebuilt, starting 300 feet above the former, and where there was 20 feet less water; this was built out 700 feet, and by offset dropped back to original line.

At Cross-dike No. 4, 150 feet of the dike was scoured out, but the wreck was removed and foot-mat laid on which the dike was rebuilt. To carry out the dikes to the distance intended will require 500 feet more on Cross-dike 5, 400 feet on Cross-dike 4, and 100 feet on Cross-dike 3, but there is yet so much to be done to secure the dikes as built, that the extension has been delayed until the mattress work is more advanced.

The matress work began May 13, commencing with "tip-mat" on Cross-dike 3. This mat rests on piles inclined from the bottom of the front row of piles to near the rider of the back row. There are as many of these inclined piles as there are piles in the front row. They are suspended from the middle rider by two parts of cable and two parts also leading to the rider of the front row. The frame of the mat is hung by wires until the mat is complete. The wires are cut and the mat dropped and loaded until sunk. In this mat the small end of the brush is at the top and bottom; the bottom extends from 10 to 15 feet outside the dike. The brush is laid diagonally in the dike to receive the support of the inclined piles in addition to the frame.

In deeper water, and where it is necessary to secure the dikes from scour before a tip-mat could be made, a flat grillage has been made.

At dikes 3 and 4, before the outer ends could be built, it was necessary to lay a foot-mat. Along the face of the main dike a foot-mat 100 feet wide has been placed—also the same around the end of Cross-dike No. 6, extending 200 feet back. For the security of the dikes and proper sinking of mat, great care has been taken to prevent drift lodging, and to remove it when so lodged. Drift rows of piling were made above dikes 3, 4, and 5, and were very useful, although considerable drift would come through, yet not too much to handle. To remove the drift a party worked ahead of the mat party and fastened the drift to the drift row, or passed it back to where the mat was sunk and let it go on the dike. The appearance of the water behind the tip-mat showed whether it was well on the bottom, and where holes were apparent we have placed small pieces of foot-mat over the hole. As the water has receded so that the effect of the tip mat can be seen, it shows that where the small end of the brush is resting well on the bottom a deposit is soon made over this brush, and the current checked; but if the mat is held up by any drift, scour occurs; there is also no deposit if the butt end of the brush is down.

During low water we were able to improve several such places, and also distribute the rock better over mat sunk in high water.

As directed, no tip-mat has been built at Cross-dike No. 6, but a grillage has been laid through it, except a small piece which will soon be completed. Bank protection

has been completed on Cross-dike No. 4 and that on Cross-dike No. 5, except loading and grading done at No. 6.

The mat party had trouble from reefs forming above the dike, so that barges of brush and rock could not be brought in. Some of this has been transferred to flats and some had to be carried over dry ground.

In working from the lower side of the dike the brush has to be turned over and passed through the dike and cables; the rock also has to be carried over the rear of the mat, which processes are slow and troublesome. It has been resorted to when it was necessary that the mat should be built and sunk.

Consolidated report, mattress work, Plum Point Dikes, from May 13 to October 1, 1884.

Dike.	Foot-mat.		Tip-mat.		Grillage-mat.		Bank protection.	
	Lin. ft.	*Sq. ft.*	*Lin. ft.*	*Sq. ft.*	*Lin. ft.*	*Sq. ft.*	*Lin. ft.*	*Sq. ft.*
Main	1,693	169,900	......	......	......	......	......	......
Cross-dike No. 1	......	......	......	......	......	......	......	......
Cross-dike No. 2	......	......	......	......	......	......	......	......
Cross-dike No. 3	......	......	1,800	112,085	300	21,000	220	8,140
Cross-dike No. 4	......	......	1,725	107,495	510	35,700	200	15,000
Cross-dike No. 5	......	......	516	36,150	......	......	......	......
Cross-dike No. 6	650	65,000	......	......	2,850	178,825	......	......
Total	2,349	234,900	4,041	255,730	3,660	235,525	420	23,140

Dike.	Materials.			
	Stone.	Brush.	Poles.	Wire.
	Cu. yds.	*Cords.*	*Cords.*	*Coils.*
Main	847.3	1,067.1	64—	50.4
Cross-dike No. 1	......	......	......	......
Cross-dike No. 2	......	......	......	......
Cross-dike No. 3	1,129.8	1,415.4	136—	66.9
Cross-dike No. 4	1,204.8	1,506.8	153—	72.2
Cross-dike No. 5	270.0	347.7	39—	16.4
Cross-dike No. 6	1,888.5	2,359.0	219.8	111.6
Total	5,340.4	6,696.0	611.8	317.5

Month.	Labor secured (days).	Labor lost (days).						Total.
		Sick.	Pulling drift.	Moving barges.	Sundays, &c.	Rain.	Miscellaneous.	
May	771.7	......	20.6	20.2	59.5	......	7.5	879.5
June	1,799.3	......	225. —	173.9	424. —	55.2	6.1	2,683.5
July	2,005.7	......	85.9	200. —	357.5	46.2	84.7	2,780.0
August	2,000.3	......	38.2	133.6	431.5	17.0	55.4	2,676.0
September	1 818.4	......	......	14. —	336. —	53.8	325.8	2,548.0
Total	8,395.4	......	369.7	541.7	1.608.5	172.2	429.5	11,517.0

Consolidated report pile-driver operations, Plum Point Dikes, from March 10 to October 1, 1884.

	March.	April.	May.	June.	July.	August.	September.	Total.
Days work of drivers:								
On dike	57	162	295	312	219	351	197	1,593
On mattress	.....	.....	23	80	38	45	28	214
Piles driven	527	891	1,899	1,449	796	1,230	480	7,272
Riders and braces	216	616	879	942	386	738	524	4,301
Hours (10 per day, each driver):								
Driving	450	1,100	2,239	2,012	1,172	1,699	806	9,477
Lost—								
Changing position	23	37	82	136	77	154	81	590
Coaling	4	21	28	57	50	96	64	319
Splicing line	.....	3	21	11	5	17	13	70
Lifting anchor	.....	12	69	32	42	4	11	161
Cleaning boiler	20	48	120	120	76	142	64	590
Rain	21	57	42	134	64	17	44	379
Out of—								
Piles	.....	185	38	55	329	593½	19	1,219½
Cables	.....	4	.....	5	87	21	3	120
Miscellaneous	47	111	77	195	143	204	65	842
Totals	115	478	468	745	873	1,247½	364	4,290½
On dike—								
Wiring	.....	30	219	361	109	542½	578	1,859½
Miscellaneous	.....	.....	10	8	34	12	25	89
Totals	.....	30	229	369	143	554½	603	1,948½
On mattress—								
Pulling drift	5	1	36	264	204	91	77	678
Placing piles	.....	.....	189	415	157	300	100	1,161
Moving barges	.....	2	2	16	5	74	87	186
Miscellaneous	.....	.....	18	79	16	4	213	329
Totals	5	3	244	774	382	469	477	2,354
Force, including pile-party and wire-party—								
Foreman	81	223	425	524	368	546	340	2,507
Engineers	69	187	363	464	320	476	294	2,172
Firemen	69	187	363	464	315	444	256	2,098
Laborers	393	1,181	2,447	2,906	1,924½	2,801	1,720	13,372½
Others	44	72	124	120	124	124	139	747
Materials:								
Feet of piling	36,910	76,173	138,979	119,790	66,706	98,753	40,009	586,919
Cables	420	697	4,500	4,508	2,196	4,453	3,309	20,142
Staples	235	129	473	808	107		.	1,842
Spikes	1,213	3,230	29,539	20,140	12,459	29,255	23,589	128,425
Drift-bolts	731	1,741	244	.....	.....	.....	.....	2,716

Number of dike.	Work performed (linear feet)														
	Previous to December 1, 1883.					December 1, 1883, to October 1, 1884.					Total to October 1, 1884.				
	Line.				Complete.	Line.				Complete.	Line.				Complete.
	1.	2.	3.	4.		1.	2.	3.	4.		1.	2.	3.	4.	
Main	2,008	2,008	2,008		2,008	1,017	1,017	1,017	950	1,017	3,025	3,025	3,025	950	3,025
Cross-dike, No. 1	794	794	794	..	794	191	191	191	.	191	985	985	985		985
Cross-dike, No. 2	643	643	643	.	643	957	957	957		957	1,000	1,600	1,600		1,000
Cross-dike, No. 3	..	..	....	.	..	2,100	2,100	2,100	.	2,100	2,100	2,100	2,100	..	2,100
Cross-dike, No. 4	..	..	....	..	....	2,000	2,000	2,000	.	2,000	2,000	2,000	2,000	.	2,000
Cross-dike, No. 5	...	...	....	.	...	2,200	2,200	2,200	200	2,200	2,200	2,200	2,200	200	2,200
Cross-dike, No. 6	....	.	.....	...	...	3,100	3,100	3,100	.	3,100	3,100	3,100	3,100	...	3,100

Consolidated report pile-driver operations, Plum Point Dikes, &c.—Continued.

	Division of force.				
	Foremen.	Engineers.	Firemen.	Laborers.	Others.
Pile party	166			1,287	
Wire party	135			1,343	
Pile-drivers	2,206	2,172	2,098	10,742½	747
Total force	2,507	2,172	2,098	13,372½	747
Lost by Sundays and holidays	344	298	290	1,809	100
Labor secured	2,163	1,874	1,808	11,563½	647

A small portion of the mat remains to be loaded when the stage of water is more favorable. The extent of the dikes obliges us to move barges a long distance by hand; this has consumed much time. Steamers have not been able to assist much. In this handling of the barges the drift row of piling has been very useful.

The map and tabular reports accompanying (Plate XIII) show the location, character, and amount of the work performed, and other items which may be of interest.

It gives me pleasure to refer to the valuable assistance I have received from Mr. James Anthony, fleet-foreman, and Mr. G. Holmes, as boarding-master.

Very respectfully,

S. P. HATFIELD,
United States Assistant Engineer.

A. J. FRITH,
United States Assistant Engineer.

F 8.

REPORT OF F. A. YEAGER, ASSISTANT ENGINEER, UPON OPERATIONS AT CRAIGHEAD'S POINT.

SIR: I have the honor to submit herewith my report of work done between Station 56 A and Craighead's Point from August 5, 1884, to October 1, 1884.

On August 5 a mat 150 feet wide was started about 100 feet below Station 56 A, and from the 5th to the 27th 1,197 feet were made and 1,097 feet sunk, 100 feet having been lost in sinking.

On the 28th a new mat 175 feet wide was commenced, with a heavy boom of cypress piling. Thirty-three feet of mat were made on the barge before shifting, and on September 2 an attempt was made to launch it, but owing to the strong current, the instant it struck the water the boom broke, and the mat doubled up and slid from the barge. This piece of mat, 33 feet by 175 feet, was sunk near the shore, and on the 3d a new one, 150 feet, was started with a boom three piling in thickness.

On the 5th this met the same fate as the other.

From the 6th to the 8th the bank was cleared preparatory to grading, and on the 9th another mat 175 feet wide was started, with two booms ten feet apart, and seven piling running up into the mat, which was commenced on the upper boom. On the 16th 38 feet were successfully launched, and held by seven lines and two wire ropes. Drift began to collect almost imperceptibly, and on the 20th the two wire ropes parted, causing the head of the mat to sink about 2 feet. On the 25th enough drift had collected to sink it 3 feet more. A large force of men was kept at work removing the drift, and on the 27th the mat looked in good condition, and preparations were made for sinking on the 29th.

The mat was now 581 feet in length, and held by six 2-inch and seven 1½-inch lines and one wire rope. On the morning of the 29th all lines parted, and the mat and mat-barge and three other barges were carried down the river.

These were landed by the Kirns, and towed back by the Kirns and Itaska.

Another mat 150 feet wide has been started, but, as per orders, it will not be launched until drift stops running.

At the place where these mats were started the river is less than 2,000 feet wide, and, as will be seen by the accompanying sketch (Plate XV), the current strikes straight into the bank at that point, making it very difficult to hold a mat there.

Caving is taking place rapidly just below the mat, but very little has taken place behind the mat.

The sand-bars on sketch are not taken from survey.

Very respectfully,

F. A. YEAGER,
Assistant Engineer.

ARTHUR J. FRITH,
United States Assistant Engineer.

F 9.

REPORT OF NEVILLE B. CRAIG, ASSISTANT ENGINEER, UPON SURVEYS, PLUM POINT REACH.

ASHPORT, TENN., *October* 17, 1884.

SIR: In accordance with instructions, I have the honor to submit the following report for the eleven months ending October 1, 1884 (Appendix F 9, and Plates I, II (2 sheets), III, IV, V, VI, and VII.)

The following is a brief summary of work done by the survey party. [Here follows a statement showing that the time of this party was well occupied.—J. G. D. K.]

During the period embraced by this report fourteen measurements of discharge were made at Fulton. The four channels at Bullerton were gauged September 15.

The meter party, under Assistant Engineer Riley, was detached from the main party, and engaged upon current observations from December 19 to February 28.

Below are given the results of all the discharge observations made subsequent to February 24. Those made previous to that date by Assistant Engineer W. H. Powless, then in charge of the party, were probably reduced and the results sent away without retaining copies. At least I can find none here.

DISCHARGE OBSERVATIONS.

	Fulton gauge-reading.	Area of cross-section.	Mean velocity per second.	Maximum velocity per second.	Discharge per second.
***At Fulton, November* 1, 1883, *to October* 1, 1884.**		*Sq. feet.*	*Feet.*	*Feet.*	*Cubic feet.*
February 25, 1884	33.56	169,635	8.64	11.54	1,466,446
February 26, 1884	33.56	170,762	8.39	11.76	1,432,774
March 12, 1884	31.45	167,760	6.34	7.82	1,067,686
March 19, 1884	31.80	167,160	7.70	9.32	1,286,273
April 3, 1884	34.97	178,200	8.26	10.48	1,472,150
April 25, 1884	30.55	161,550	7.43	9.15	1,201,025
April 26, 1884	30.47	161,550	7.14	9.04	1,153,450
May 8, 1884	29.10	153,610	6.987	8.47	1,073,313
May 9, 1884	29.52	154,722	7.21	9.08	1,115,605
May 24, 1884	21.65	131,340	4.50	5.82	591,350
June 21, 1884	20.55	131,480	4.49	5.67	590,063
August 6, 1884	14.34	112,190	3.441	4.15	386,117
September 16, 1884	6.90	92,710	2.003	2.33	180,710
***Near Fulton Section, head of Island* 34.**					
May 9, 1884	29.44	209,120	4.452	5.11	931,018
***Bullerton, September* 15, 1884.**					
Bullerton Chute	7.15	20,480	1.65	2.065	33,895
Channel outside Bullerton	7.15	23,020	1.666	2.577	38,349
Middle Bar Channel	7.15	13,340	3.348	4.252	44,662
Yankee Bar Channel	7.15	13,600	1.920	2.627	26,186
Total discharge					143,092

The meter party, under Mr. Riley, failed to accomplish anything owing to the strong current at the old Fulton gauging section, and the inability of the launch to do the work required of her. All the results given below were obtained by the method of double floats.

It will be observed that two sections were gauged at Fulton on the 8th and 9th of May.

The first gauging was done on the old gauging section. Then the new gauging section, just above the head of Island 34, was gauged; after which discharge observations were again made on the old section.

The two sections were opposite in character, the old being narrow and deep, the new wide and very shallow. They were so situated that gauging them was equivalent to gauging behind a submerged dam and then on its crest.

As anticipated, widely divergent results were obtained, as the following comparison will show:

	Date.	Time.	Area.	Mean velocity per second.	Discharge per second.	Fulto gaug readi
			Sq. feet.	*Feet.*	*Cubic feet.*	
Old section observed	May 8	10.21 a. m.	153, 610	6. 987	1, 073, 313	29.10
Do	May 9	2.45 p. m.	154, 722	7. 210	1, 115, 605	29.53
Old section computed	May 9	10.00 a. m.	154, 537	7. 173	1, 108, 494	29.44
New section observed	May 9	10.00 a. m.	209, 120	4. 452	931, 018	29.44

The third column is computed from the first and second, on the supposition that the area and mean velocity vary uniformly with the gauge-reading during the interval. The constant variation in the cross-section at the old gauging section is deserving of careful study. I am convinced that the section constantly endeavors to adapt itself to the discharge, but when a sudden change in stage occurs, the section is larger or smaller, as the case may be, than the discharge requires; and at such times gauging is erroneous from considering an area that is either not wholly effective for discharge, or so much less than the discharge requires that for the time being the law of velocity in a vertical plane is changed. A number of facts lead to this conclusion, but additional observations taken with particular regard to this subject are required before the inference can be regarded as fact.

It is my hope that discharge measurements may be in future a more prominent feature in the work of the party.

THE LEVEE SURVEY.

This survey was begun June 24, under instructions to make a survey, plans, and estimates for a levee that would prevent the escape of water over Plum Point. The first part of the work involved a survey of the old Ashport levee, extending from Ashport to the bluffs, 8 miles back. Cross-sections of the levee were taken every 100 feet and at many intermediate points.

I found the levee in a very fair condition, but it seems to have been built on the supposition that high water at the bluffs would be about the same level as at Ashport, while as a matter of fact there was a difference in the high water of 1882 at the two places of about 4 feet, being highest at the bluffs.

As a consequence, almost the first flood after its construction ruined it, and the badly damaged portion is all at the end next the bluffs, while near Ashport the levee is for a long distance still perfect. From Ashport our location is along the river, at varying distances from it, to the head of Yankee Bar. It then follows a ridge back of Crutcher's Lake and strikes the main bank of Old River back of Flower Island, which it follows for a mile and a half, and then runs directly to Cold Creek, which it meets about 1 mile above its mouth.

I regret that deficiency in the office force and the short time allowed for the preparation of this report render it impossible for me to present the results of the survey here.

The line was completed August 31.

SUMMARY OF CHANGES ON THE REACH.

A map showing scour and deposit on the entire reach was made some months ago, but without a pantagraph I am unable to make a reduction of it to a smaller scale in time for this report.*

* Blue prints of this were distributed to the Mississippi River Commission. The map, if reproduced here, would be apt to mislead, as the comparison was of low-water stage, with a following intermediate falling stage. Results shown would be greatly modified by the following falling river. J. G. D. K.

In an accompanying diagram (Plate III) I have, however, given graphically a comparison of effective low-water cross-section areas for three surveys, viz. that made in the fall of 1881, that of October, 1883, and the last general survey, made in May and June, 1884. Maps are also submitted showing the condition of the river in the vicinity of Bullerton Towhead (Plate VII) and the Gold Dust Dikes (Plate VI) from surveys made during the lowest water of the season. Accompanying each of these two maps are comparisons (Plates IV and V) of the present condition of the river in the localities mentioned with that shown by the survey of October, 1883.

The most remarkable and sudden changes on the reach are those which have occurred in the Bullerton Channels. During the last high water a general deposit took place over nearly the whole area of Bullerton Chute, as shown by the survey of April 15, and just outside the opening in the Osceola-Bullerton Dike; this deposit attained a maximum depth of 27 feet.

Such an obstruction in what had been the main channel brought an increased force against the weaker portion of the dike at the foot of Osceola Bar, and it gave way.

A large amount of water began passing into Bullerton Chute through the break in the dike, and scoured the channel deeper as the water fell.

At a lower stage a general deposit in the main river opposite and below Bullerton resulted, and the extremely unfavorable state of affairs shown by the survey of May 22 ensued. The building of the cross dikes on ranges 48½ and 51½ in Bullerton Chute went far, however, to rectify the mischief done, and in a few weeks' time the river cut a steamboat channel through the immense bar in the middle of the river, as shown by the survey of August 4. This cut through the bar, by diminishing the current in the channel just outside Bullerton, acted rather unfavorably upon the old Bullerton crossing at Bullerton light, which for a time became extremely troublesome to all the larger steam and tow boats, until about the middle of August they abandoned it entirely in favor of the middle-bar channel. This state of affairs existed during the latter part of August and the first fifteen days in September. The extension meanwhile of Dike No. 6, the lowest of the Hotchkiss dikes, was operating gradually to make the middle-bar channel difficult of entrance above, narrow and crooked in places below. Steamboats frequently ran aground, and in one instance a fleet of five barges of the Saint Louis and Mississippi Valley Transportation Company broke and ran aground in it.

About this time the Bullerton survey of September 13 revealed the fact that the old Bullerton crossing had been scouring and straightening itself, and that there was a clear 12-foot channel for the stage then existing.

A few days later all the boats in the river were using this channel, and the middle bar channel was completely abandoned.

CAVING BANKS.

The following are the most noteworthy cases of caving banks on the reach:

(1.) On the Arkansas side of the river immediately above Daniel's Point a large amount of caving occurred during the subsidence of the last high water.

(2.) Some caving has been going on constantly on the outside of Ashport Bar, R. 22–24, but is not important.

(3.) On the Tennessee side, between R. 22 and R. 26, the caving is quite rapid during the falling stages succeeding high water. This caving attains its maximum at a point above 750 feet below R. 25, where between the surveys of October, 1883, and April, 1884, the caving amounted to 400 feet. The significance of this fact is seen when it is stated that from R. 21 to R. 25 several sloughs and low banks permit an enormous volume of water to escape into the low ground a quarter of a mile beyond where the levee survey shows a dry lake or slough of immense size leading directly to Cold Creek. Every foot that caves here serves to weaken the slight barrier that now remains, and increases the probability that Plum Point may, before long, be called Plum Island.

(4.) From R. 30½, just below Fletcher's, to R. 36, at Elmot, the worst case of caving on the reach occurs.

From October, 1883, to May, 1884, the caving was as follows: R. 31=100 feet; R. 32=210 feet; R. 33=385 feet; R. 33½=700 feet; R. 34=385 feet; R. 35=10 feet; R. 36, slight.

Since the May survey, the caving has been more rapid on the lower ranges near Elmot, and not so great upon those above.

(5.) There has also been considerable caving going on between ranges 34 and 36, inside Elmot Bar, which, on range 35, amounts to about 270 feet, between October, 1883, and the present date.

(6.) On the Arkansas side, back of Bullerton Tow-head, R. 50½–R. 54, the maximum caving amounts to about 100 feet, between October, 1883, and May, 1884.

(7.) Between the same dates, the head of Yankee Bar has receded 740 feet downstream.

(8.) The whole shore-line on the Arkansas side, between Pettey's Landing and R. 70, at Craighead Point, has been caving rapidly. From October, 1883, to June, 1884, the greatest caving was between R. 61 and R. 71, reaching its maximum at R. 63, where it amounted to 380 feet. Since June, 1884, the caving has been more rapid above, and principally due to the impinging force of the strong current passing through the middle bar and Yankee Bar channels.

I regret that the brief time allowed for the preparation of this report has rendered it impossible for me to even gather together and examine many of the maps and computations on file at Elmot and at Cairo, which would be absolutely necessary to make this report thorough and complete. My present assistants, Messrs. Maurer and Sturtevant, as well as those lately connected with the party, Messrs. Hiroi and Hall, have rendered valuable service.

Mr. Maurer, particularly, is deserving of the greatest credit for the faithful and painstaking manner in which he has done the draughting and made all necessary reductions.

Mr. Herman, though only serving as level rodman, has frequently done efficient service with the transit.

Very respectfully, your obedient servant,

NEVILLE B. CRAIG,
United States Assistant Engineer.

A. J. FRITH,
Assistant Engineer.

APPENDIX G.

REPORT OF CAPTAIN CLINTON B. SEARS, CORPS OF ENGINEERS, UPON OPERATIONS IN THE SECOND DISTRICT.

(Maj. A. M. Miller, Corps of Engineers, U. S. A., in charge, to September 1, 1884; Capt. Clinton B Sears, Corps of Engineers, U. S. A., in charge (temporarily) since September 1, 1884.)

This district extends from the foot of Island 40 to the mouth of White River. The improvements of two reaches only in this district have so far been contemplated, viz. the Memphis and Helena reaches. Owing to a want of funds, nothing has been done on the latter reach beyond a survey, nor has any project for its improvement been made.

1. *Memphis Reach and Harbor.*

(Assistant Engineer W. M. Rees, in local charge.)

The original project for the improvement of this reach, submitted by Major Miller and approved by the Commission, contemplated the narrowing of the river below Island 40 to an average of 3,000 feet by closing Beef Chute, east of Island 40 (in first district), by building up the bar from Ash Slough to foot of Island 40, by means of dikes, and by the same means to build up artificial banks on the opposite side in the Ash Slough Bend and at the bend above Mound City; to close Frame's Chute at high water, and to hold the caving banks in Hopefield Bend, on the Arkansas side, and to do the same on the Tennessee side from Frame's Chute to mouth of Wolf River, and below the latter as far as may be necessary for the preservation of the city front. Below Fort Pickering to close the chute to the east of President's Island by dikes.

This project has been carried out only as far as relates to the revetment work in Hopefield Bend, and above and below the mouth of Wolf River. No dike work has been done.

Revetment work has been carried on at intervals through two years as rapidly as the funds available and the state of the river would permit.

HOPEFIELD BEND.

This revetment consists of a subaqueous mattress, about 140 feet wide, and an upper bank brush revetment laid on a graded bank and well ballasted with stone. Up to November 1, 1883, 6,700 linear feet of subaqueous mat had been sunk and 4,100 linear feet of upper bank protection had been placed.

During the last eleven months the work has been carried on as energetically as possible, but under many adverse circumstances, and has been attended with many losses, caused by drift accumulations and strong currents. Much damage has been done by the flood to the work at the head of the bend, and all of the subaqueous

mattress from where the upper bank revetment ended down to the end had disappeared after the flood.

This is supposed to be lying on the bottom of the river, and may have some beneficial effect in retarding the deepening of the channel where it lies.

The flood of 1884 left only some 5,700 linear feet of bank protection in fair shape. No caving of importance took place along this piece, but below it where the upper bank had not been revetted extensive caving took place.

The revetment at the upper end of the bend has been repaired and the subaqueous mat and upper bank protection has been continued down-stream from the end of the uninjured portion of last spring.

The subaqueous mats have been made wider and stronger, the upper bank protection has been made thicker, and greater care has been taken to connect the upper and lower bank revetments.

It is expected that the main portion of this work will be completed before the next high water.

For details of manner of construction, cost, progress, and condition of work, October 1, 1884, see Assistant Engineer Rees's report herewith, marked Appendix G 1, and map marked Appendix G, Plate I.

MEMPHIS HARBOR.

The work here is local and for the protection of the city front, which is covered with costly buildings, such as elevators, cotton sheds, warehouses, oil mills, railroad depots, &c.

Just below the mouth of Wolf River the whole main channel of the river strikes the shore almost at right angles; the current is very strong and the channel very deep, having at some places 100 feet at 11.4 feet on Memphis gauge, and this within 300 feet of the shore.

These conditions, taken in connection with the hindrance from buildings on top of the bank and extending down to the water, the constant use of the banks for steamers, barges, ferry landings, coal fleets, and railroad transfer landings, cause any attempts to protect this front to be attended with many and serious difficulties.

An effectual protection should consist of a continuous subaqueous mattress, at least 300 feet wide, of double thickness and well ballasted with stone; of an extra thick and strong upper bank revetment, solidly covered with stone, and laid on a grade not less than one to four, and of a strong brush mat connection, woven into the upper work and lapping well over the lower work.

These conditions we have been unable so far to fulfill as regards width of lower mat. The two abortive attempts to sink wide mats are described in Mr. Rees's report.

The reason of this failure was that these mats were not strong enough to stand the great cross-strains thrown onto them while sinking. Had it been practicable to have evenly distributed the strains on the lines and rods, so as to have given equal bearings, it is possible the mats would have proven sufficiently strong. The factors in the problem are, however, so uncertain that it will be necessary to add large factors of safety to the mat to allow for unequal strain.

Preparation had been made for a new mat, 250 feet wide, to begin just below Wolf River, and the rods, rope, &c., prepared, when the river suddenly rose some 8 or 9 feet, bringing down considerable drift and greatly increasing the current, and it was deemed advisable to wait for lower water.

In the fall of 1882 two mats, each 120 feet by 60 feet by 2 feet, were sunk in front of the cotton platform at the foot of Winchester street, and 14 mats of the same dimensions each (except one which was 120 by 40 by 2 feet) were sunk parallel to each other and extending from the foot of Market street to the foot of Poplar street.

In 1883 five mattresses, each 120 by 60 feet, were sunk, three near the cotton compress and two in front of the city landing, and the bank was graded and revetted from the elevator to the cotton compress.

Owing to limited means this work was put only at the points of greatest danger, but being fragmentary and detached did but little good.

Upon the allotment of more ample funds the continuous upper and lower revetment was projected and has been carried out as effectively as possible in the face of the difficulties encountered.

Portions of the two wide mats that broke in sinking were secured and sunk in front of the elevator. A subaqueous mat 150 feet wide now extends from a point about 500 feet above Wolf River, continuously across the latter and down to near the foot of Jefferson street. This overlies the mats previously put down and the two portions above mentioned for a distance of 960 feet, and in front of the elevator there are three thicknesses.

But little trouble has been experienced in sinking this mat, and no loss.

The upper bank has been graded to the foot of Exchange street, and about 500 feet has been revetted and well ballasted.

It is expected that the grading and upper bank protection will be completed to the foot of Jefferson street, where the levee pavement begins, and the narrow lower mattress sunk to the foot of Beale street before high water; also, a sill mattress laid fore and aft in Wolf River and extending well out across the present shore mattress.

If the next attempt at sinking a wide mattress be successful, its construction will be continued down as far as the money and season will permit.

FINANCIAL STATEMENT.

Memphis Reach and Harbor.

Amount allotted by appropriation of—	
August 2, 1882	$325,000 00
January 18, 1884	90,000 00
July 5, 1884	200,000 00
	615,000 00
Total amount expended to September 30, 1884	431,672 97
Balance available, October 1, 1884	183,327 03
In treasury	110,000 00
In hands of Captain Sears	73,327 03
	183,327 03

The condition of the records in this office is such that a classified statement of expenditures previous to September 1 is impossible, Major Miller having taken his retained vouchers with him, and there being no copies on file.

For details of construction, cost, and condition of work, October 1, 1884, see Assistant Engineer Rees's report herewith, and map.

SUMMARY.

As the work so far done on this reach is only preliminary and partial, is is not deemed advisable to attempt any comparisons with a view to determining the improvement brought about by the work so far done as regards channel improvement.

It is not expected that bank revetment will have any positive effect in improving a channel-way. The good to be expected is negative to the extent of holding a certain amount of earth in place and keeping it from washing into the channel and forming bars below.

It is positive to the extent of maintaining a regular and well defined channel and in preventing a cut-off, which might unsettle the regimen of the river for miles below.

The original project has been set forth above. No important changes have been made in the general plan.

The total amount expended to November 1, 1883, was $268,269.64. During the eleven months ending October 1, 1884, there have been expended $163,403.33. During the next year, $100,000 can be profitably expended towards carrying out the original project. With this it is proposed to revet some 15,000 linear feet of bank, and to build some of the pile dikes.

My experience shows me that the estimate made by Major Miller in November, 1882, was much too low, and I have estimated my revetment work at $20 per linear foot, and dike work at $8 per linear foot.

The advantages and benefits to be expected from this expenditure are those incident to the completion of the general project for the reach, viz: Narrowing and deepening the channel, giving its banks stability and protecting the valuable property along the Memphis City front.

An estimate for the entire and permanent completion of the work of improvement on this reach, I am unable to give, not knowing the intentions of the Commission as to the ultimate extent of the works.

As this work is only one link in the chain of general improvement of the river, the amount of commerce and navigation that will be benefited is that incident to the whole river, a statement of which has already appeared in a previous report of the Commission.

The present estimated value of the plant, tools, and outfit on hand belonging to the reach is $118,000.

LEVEES.

The funds for levee construction in this district having been exhausted at the date of the last annual report, no levee work has been done. From the July appropriation for 1884 the Commission allotted $160,000 for the repair and preservation of levees in

the second, third, and fourth districts, this to be divided by the board of district officers. The division was made, and $20,000 conditionally allotted for repairs to levees on Yazoo Front, second district.

The conditions of its allotment having by September 10 not been fulfilled, this money reverted to the Yazoo Front, third district. Since then, however, the local levee authorities of the Yazoo Front, second district, have succeeded in negotiating their bonds, and contracts have been made for the expenditure of some $500,000 in levee work.

The Commission also allotted $15,000 for the repair and strengthening of the Long Lake Levee in Arkansas, providing the levee from Helena to Long Lake shall be repaired and raised to 2 feet above the high water of 1882 prior to November 1, 1884, and, furthermore, provided that the district officer upon examination of such levee shall find its condition to be such as to require such repair for its safety.

A personal examination by the district officer was made in September and the need of its repair determined. The local levee authorities have made a contract for the work from Helena to Long Lake, to be done by October 31. It is expected, therefore, this $15,000 will be expended as above.

Respectfully submitted.

CLINTON B. SEARS,
Captain of Engineers, U. S. A.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., October 10, 1884.

CAPTAIN: I have the honor to submit a report of the improvement of Memphis Reach and Harbor from November 1, 1883, to October 1, 1884. The work comprises the protection of the banks in Hopefield Bend and in Memphis Harbor.

HOPEFIELD BEND.

The original project was to begin at Mound City Chute, and revet the bank for a distance of 2 miles, towards Hopefield, Ark., leaving the lower portion of the bend unprotected so as to allow the river to straighten itself by cutting away the point at Hopefield, which would decrease the pressure now exerted against the Memphis Front. The revetment to consist of brush mattress work, covered with stone, extending from the bed of the river to the top of the bank. This work was begun in December, 1882, and up to November 1, 1883, 6,700 linear feet of lower bank had been revetted, and 4,100 linear feet of this had been extended to or near the top of the bank. At the close of the working season of 1882–'83 (January 4, 1883), 10,400 linear feet of the below-water bank had been revetted, and 5,700 linear feet of upper bank work completed. The deep-water mattresses were 140 feet wide, built and sunk in lengths of about 1,000 feet. The upper bank revetment consisted of two layers of brush, secured with poles and wires, and were covered with stone—this was to be placed upon a slope of 1 on 3, graded by the hydraulic process, and to extend to the top of the bank, but, owing to lack of sufficient grading power, the slope was in most places greater, and not extended to the top of the bank. In many places it was 1 on 2 or 2½, ending against a hard stratum of buckshot earth, 6 to 10 feet below the top of the bank. Two grading machines were used, the one a Dayton cam pump, described in my report of last year, which has a steam cylinder of 16½ inches diameter, water cylinder 9 inches diameter and 18-inch stroke, discharging 325 gallons per minute at 140 pounds pressure, and removing about 60 cubic yards of earth per hour. The other was a pile-driver pump (Knowles duplex), having 10-inch steam cylinders, 6-inch water plungers, 12-inch stroke, discharging about 200 gallons per minute at 160 pounds pressure. As the pump worked but a short time and in hard material the quantity cut per hour was only 16 cubic yards.

During the low water of 1883 it was decided to build the deep-water mattresses continuously, but the river began rising in November, piling drift against the mooring barge and mat to such an extent that, on November 14, I was obliged to sink it, after 2,571 linear feet had been made.

On November 30 a mat 1,057 by 140 feet was lost while attempting to sink. Nine lines, varying in diameter from 1½ to 2 inches, were parted, due to the great strain brought upon them by drift which had accumulated in considerable quantity above the mooring barge and under the head of the mattress. Work, however, was still continued; more and larger lines were placed both to the mooring barge and to the head of the mattress.

Two mattresses were sunk after this, when work was suspended in the lower portion of the bend, and the ways moved to near Mound City Chute to repair the damage caused by a large cave, which occurred on December 12, breaking up the revetment placed during the season of 1882 and 1883, for a length of about 500 feet, and width

in the middle of 175 feet. The large deep-water mattress broke in small sections and was carried away. When this mattress was sunk it reached practically to the foot of tne slope.

An examination, made after the caving, showed that the depth along its outer edge had increased from 40 to 75 or 80 feet. This increased depth was undoubtedly due to the caving away of the bank above, where no revetment had been done, leaving the revetted point projecting in the river; an additional cause may have been that our fleet of boats had been lying for some time at this place. Several smaller caves occurred in the upper bank later, all being where boats were lying along the bank or above mooring barges where drift had accumulated. After the boats were removed no caving occurred along this portion of the bank. The river continuing to rise, all work was suspended on January 23, 1884.

At this date there was needed to complete the work laid out for the season 1,000 linear feet of deep-water mattress, in lower portion of bend; 800 linear feet to cover space at mouth of Mound City Chute and the banks just below, and 5,600 linear feet of upper bank revetment from 60 to 75 feet wide. Over one-half of the work done during the season of 1882–'83 had disappeared, although it had successfully withstood the high water of 1883.

An examination, made after the subsidence of the high water of this year, showed a considerable amount of caving in the lower part of the bend, commencing at the end of the upper bank revetment and extending to Hopefield, where the sites of ten buildings were washed away. Wherever the revetment had been carried to or near the top of the bank very little caving had taken place, only a few minor breaks having occurred in the upper revetment, all of which have been readily repaired. Five thousand seven hundred linear feet of revetment withstood the high water of 1884.

Along that portion of the bank where no shore-work was placed, the bank caved, the widths of caving varying from 200 feet near the middle of the bend to 700 feet near Hopefield.

This destroyed 4,500 linear feet of deep-water revetment; add to this 500 linear feet lost in December 18, 1883, the total is 5,000 linear feet of revetment lost or nearly 50 per cent., but the greater portion of this was incomplete work, not being extended above the low-water line.

The conclusion drawn is that if the revetment had been completed it would have successfully stood the high water of the spring of 1884. The project for this season's work is, first, to repair and strengthen the revetment that held, extending the same nearer to the top of the bank where practicable; second, to replace the deep-water mattresses in the lower part of the bend, lost last season, for a distance of 5,000 linear feet; third, place a mattress across the mouth of Mound City Chute, extending the same to cover the break below, a total length of 800 feet. The revetment in a[illegible] cases to be extended to the top of the bank, which will first be graded to a slope of [illegible] on 3.

Some modifications have been made in the former method of construction, viz, th[illegible] width of deep-water mattresses has been increased to 150 feet, and the shore-edge i[illegible] held against a line of piling driven 8 feet apart, and on a line about 5 feet below lo[illegible] water; this will increase the width of the revetment from 25 to 30 feet. The mattresses are being made thicker and stronger by weaving brush around but 2 poles instead of under and over for the whole length of the brush, then throwing the tops on the mattress. These tops are secured by a binding pole well wired to the weaving poles, and transverse poles are placed over the binding poles, spaced 8 feet apart. In addition 5 one-half inch iron rods and 2 five-eighth inch wire ropes are run through the mats longitudinally, and one-half inch iron rods or wire ropes are run through transversely every 40 feet, the ends of the latter being secured to piling or to the shore; all rods and wire ropes are well secured to the mattress at numerous points with wires.

The construction of shore work is about the same as last year, except that considerable wire rope is used and a much greater quantity of stone.

The shore work will extend outside of the line of piling and lap the deep-water mattress about 20 feet; it will be double the thickness of the latter. Work was begun on August 14, 1884, with one screen barge for building foot-mats, one pile-driver and one grader-boat. On September 12 the work of building deep-water mattresses was begun; good progress has been made, and it is expected that with favorable conditions of the river the projected work will be completed by December 1, 1884.

The work done for the eleven months ending October 1, 1884, is as follows:

Deep-water mattress made:		
5,539 by 140 feet	}..squares..	9,6[illegible]
1,278 by 150 feet		
Deep-water mattress sunk:		
4,895 by 140 feet	}....do....	8,5[illegible]
1,115 by 150 feet		

Deep-water mattress lost in sinking, 1,260 by 140 feet	squares..	1,764
Shore protection completed	do....	4,466
Earth removed by hydraulic grader	cubic yards..	30,451
Earth removed by hand grading	do....	3,888
Number of piles driven		338

(See annexed tables for cost of work, material used, &c.)

MEMPHIS HARBOR.

The project for the protection of the harbor is to revet the banks in a manner similar to the work at Hopefield Bend, commencing at about 1,000 feet above the mouth of Wolf River, and extending the same to the end of the paved levee at the foot of Beale street.

Owing to the depth of water, mattresses were to be constructed 200 to 300 feet wide, in order to reach the foot of the slope.

During the high water of last spring the bank caved at a number of places along the city front. This caving continued until the river reached its lowest stage, in August, 1884.

The locations are as follows: From the mouth of Wolf River to foot of Market street, a distance of 1,200 feet, the average caving is 85 feet, being 140 feet a short distance below Wolf River, 90 feet at middle of Memphis Compress Company's shed, 70 feet at foot of Winchester street, and 25 feet at foot of Market street.

A portion of the Compress Company's buildings were removed or caved in the river, viz, a cotton shed 178 by 48 feet, and platform 245 by 50 feet.

The Panola Oil Mill Company lost part of their building, viz, frame portion 140 by 45 feet, and brick portion containing their elevating machinery, 50 by 45 feet. Between the south side of market street and the Memphis Grain and Package Company's elevator no caving occurred. At the lower side of the elevator the caving was 300 feet long by 30 to 50 feet back, destroying a portion of the building, 226 by 96 feet, which contained three steam legs or inclines used in loading and unloading steamboats, and caused the company to discontinue their large river business.

At the Hanover oil mills a piece 150 feet long by 25 feet deep caved; this extended back to the foundation walls of the mill, threatening to undermine them. For their protection two large loads of stone, containing 479 cubic yards, were given by the Government to the mill company and placed on the caving bank during the early part of June. This appears to have arrested the caving.

At the foot of Jefferson street a piece of the paved levee, 130 by 75 feet, caved in. This was a top-bank cave, the piling below not being disturbed, and was probably caused by the whirls and eddies caused by a sunken barge just above.

No other caving took place along the levees except a slight settling of the lower portion for a length of about 300 feet, between Jefferson and Court streets. Along the high bluff below the levee, caving took place at a number of places, only two, however, being of any extent. The first, between Linden and Pontotoc streets, was 175 feet long by 35 feet back; the second, south of Vance street to the De Soto oil mill, was 375 feet long by 113 feet back; this carried away the end of a large ice-house and a corner of the De Soto oil mills.

All the above is along the city's water-front, where valuable business properties are located. Work was begun July 29, by placing mooring-barges in position about 500 feet below the mouth of Wolf River. These were made from two coal shells and placed end to end, the total length being 350 feet. Two mattress ways, each 160 feet long, were placed end to end below, and a mat of the usual construction, 144 feet wide, built on each; the space between of 12 feet was to be covered with brush poles and iron tie-rods, these making the mattress 300 feet wide. After building this 289 feet long, the drift had accumulated under the outer barge and mattress to such an extent that the first attempt to sink wide mats was abandoned and the outer mat dropped below the inner.

On August 12, the construction of a mattress 300 feet wide was begun; great care was taken in its construction and also in mooring it to the shore.

Two five-eighths inch iron rods, ten one-half inch iron rods, and three five-eighths inch wire ropes were run through it longitudinally. It was held to the mooring barge by 1-inch and 1¼-inch slip lines at every 16 feet across the head. Seven shackle lines from 1½ to 2 inches diameter ran from the head to the shore, whilst the mooring barge was held in place by nine lines of from 1½ to 2½ inches diameter, all the lines having long leads. In addition the mattress was fastened to shore by diagonal lines running across it at about every 100 feet in length.

After completing 690 linear feet, an attempt was made to sink. The entire mat was well ballasted and the head sunk to the bottom, when it broke straight across a short distance below the middle. The lower portion swinging around, was checked and sunk in front of the elevator. Another mattress 250 feet wide was immediately begun, additional strength being added in the shape of iron rods and cables; this also

broke when being sunk, parting the iron rods and wire rope; about half of it was secured and sunk in front of the elevator. Immediately after this second failure two mattress ways were started to build mattresses 150 feet wide, the intention being to place wider mattresses on top of these as soon as material for their construction could be obtained, the fact being recognized that in this deep water and strong current mattresses must be constructed much stronger than even heretofore.

It is proposed to build the next mattress during low water, to make it 500 feet long and 250 feet wide, to bind to it longitudinally 12 three-fourths inch iron chains, 8 five-eighths inch iron chains, 3 2-inch manila ropes, 2 one-half inch sisal ropes, and transversely every 40 feet apart to place across the mat chains of one-half inch iron, all the iron chains to be made in links of 16 feet, well twisted together. Additional and heavier mooring shackles and diagonal lines will also be attached to the mattress.

On the 30th September the bank was revetted with mattresses 150 feet wide, from 500 feet above the mouth of Wolf River to 150 feet above Jefferson street, a length of 3,925 feet. This revetment is doubled for a length of 960 feet between Winchester and Exchange streets, while in front of the elevator there are three thicknesses of mattresses.

The work done for the eleven months September 30, 1884, is as follows:

Deep-water mattress made:		
761 by 144 feet	squares	9,526
690 by 300 feet		
479 by 250 feet		
3,442 by 150 feet		
Deep-water mattress sunk:		
761 by 144 feet	do	7,828
365 by 300 feet		
300 by 100 feet		
240 by 250 feet		
3,158 by 150 feet		
Deep-water mattresses lost in sinking:		
225 by 300 feet	do	1,272
239 by 250 feet		
Earth removed by hydraulic grader	cubic yards	2,870
Earth removed by hand grading	do	3,620
Shore protection completed	squares	799
Number piles driven		16

(See annexed tables for cost of work, materials used, &c.)

PLANT.

The following is a list of the plant on the reach: 1 tow-boat, 5 quarter-boats, 4 mattress-boats (2 belonging to Lake Providence reach), 4 screen-boats, 1 machine-shop boat, 1 hydraulic grader, 4 mooring barges, 22 decked barges, 9 pile-drivers, 1 bakery-boat, 2 coal-shells, and 5 small flat-boats.

Estimated value, exclusive of two Lake Providence mattress-boats, $118,000.

All the above is in serviceable condition. Upper cabins were added to two of the quarter-boats, thus nearly doubling their capacity. I have now accommodations for 500 laborers.

Our hydraulic grader was found too light to carry heavy pressure, so two pile-driver pumps were placed on one driver and connected. The old grader delivers the water to this pair of pumps at a pressure of 100 pounds. The result is that the work done is nearly double what both machines would do singly at 140 pounds' pressure.

Improvements were made to mattress-boats by placing platforms on each end, thus increasing the length by 12 feet and adding two more runs, so that mattresses are now built 150 feet wide instead of 140 as heretofore.

Two mooring barges were built from coal shells and two from coal barges. All are well strengthened with iron tie-rods and well supported with bitts, kevels, chocks, &c.

A bakery-boat was fitted up with two large, wrought-iron ranges. Two small barges were built for distributing supplies; a tug was chartered by the day to do the work on the reach. The steam launch Daphne exploded her boiler on August 21, killing three men.

SURVEYS.

A survey party was organized in June, and triangulated the reach from Island No. 40 to the head of Vice-President's Island. The bank and bar lines have been located and compared with surveys of former years. Forty-six ranges were established and sounded. Soundings were repeated every ten days on ranges where revetment had been placed, to determine if possible if any changes took place in depth of channel due to revetment.

These soundings were also compared with those taken in 1882 and 1883. From the data collected it is impossible to determine whether or not the channel deepens along the revetted bank.

The banks have caved at a number of places. Above the mouth of Wolf River, the caving extended 2,700 feet as follows; (1) 1,000 feet, 80 feet back; (2) 1,000 feet, 100 feet back; above, 30 feet back; area covered, 4½ acres.

Just below mouth of Wolf River, bank has caved 600 feet since 1867, 250 feet since 1877, 40 feet during past year. Area covered between mouth of river and foot of Market street, 2½ acres.

The length of the caving on Hopefield Bend was 8,750 feet; average width, 400 feet; area about 80 acres.

Above Mound City Chute the length caved is 3,500 feet; width average 50 feet; area, 4 acres. Very little caving occurred above Old Hen Island, although for several years back there was considerable there.

The sand-bar opposite Memphis has increased in size, narrowing the river very much during low stage. Comparing the surveys of 1882 and 1884, both taken at the 11.4 stage, the encroachment of the bar towards Memphis side, is 750 feet. The width of river at foot of Jefferson street at 11.4 stage was 1,650 feet in 1883, and 1,300 feet in 1884.

The bar opposite Hopefield Bend moved down 3,000 feet since October 1883, the width of river at 11.4 stage being 1,590 feet.

Total revetment completed November 1, 1883, *to September* 30, 1884.

	Squares.
Hopefield Bend	12,991
Memphis Harbor	8,627
Total	21,618

Cost of above (*not including plant and equipment*).

Survey	$2,030 06
General service, coaling steamers	502 28
General expense, office and fleet	19,306 28
Tow-boat service	15,415 61
Construction and repairs to plant and machinery	14,623 27
Revetment:	
Hopefield Bend	56,198 10
Memphis Harbor	39,094 12
	147,169 72
Cost of revetment per square of 100 feet	6 80
Cost of revetment per linear feet of bank for mattress 150 feet wide and shore work 100 feet, on slope of 1 on 3 (approximate)	17 00

TABLE 1.—*Hydraulic grading.*

HOPEFIELD BEND

Ten days ending—	Linear feet.	Cubic yards.	Time worked.	Cubic yards per hour.	Average pressure in pounds per square inch. Steam.	Average pressure in pounds per square inch. Water.	Strokes per minute.	Coal.	Composition of material. Buckshot.	Composition of material. Clay.	Composition of material. Sand.	Cost per cubic yard.	Cost per linear foot.	Total cost.
1883.			*Hours.*					*Bush.*	*Pr. ct.*	*Pr. ct.*	*Pr. ct.*	*Cts.*	*Cts.*	
Nov. 10	320	2,230	47	62.9	90	164	88	62	34	50	16	4.9	35	$110 77
20	400	2,375	54	45.8	87	140	84	90	42	40	18	4.9	29	115 70
30	1,320	5,010	57	87.9	84	136	72	130	86	5	9	2.5	10	127 75
Dec. 10*	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	875	3,945	56	70.4	90	140	71	115	81	13	6	3.2	14	125 74
31	495	2,925	44	61.9	90	140	69	75	82	11	7	3.6	21	105 13
1884.														
Aug. 30	498	4,216	67	62.9	80	125	66	61	.	60	40	3.0	25	124 44
Sept. 10	335	3,513	87	40.2	80	125	66	50	73	....	27	3.3	35	116 43
20	332	†3,377	85	30.3	80	125	60	60	54	34	12	3.5	35	117 50
30	397	3,960	58	66.2	80	125	68	42	66	......	34	2.7	27	106 10
Total	4,970	31,581	555	....	....	....	....	685	....	....	....	....	.	1,049 56
Average	.	....	..	57	..	.....	.	....	.	.....	.....	3.32	21	......

*Suspended on account of high water.
†Of this amount 2,789 cubic yards have been graded at Memphis Harbor.

TABLE I.—*Hydraulic grading*—Continued.

WITH PILE-DRIVER, No. 37, M. R. C.

Ten days ending—	Linear feet.	Cubic yards.	Time worked.	Cubic yards per hour.	Average pressure in pounds per square inch. Steam.	Average pressure in pounds per square inch. Water.	Strokes per minute.	Coal.	Composition of material. Buckshot.	Composition of material. Clay.	Composition of material. Sand.	Cost per cubic yard.	Cost per linear foot.	Total cost.
1883.			*Hours.*					*Bush.*	*Pr. ct.*	*Pr. ct.*	*Pr. ct.*	*Cts.*	*Cts.*	
Dec. 20	200	820	45	18	90	155	109	70	96	10	4	8.6	35	$60 94
31	220	830	60	14	90	165	120	45	90	8	2	7.3	27	59 45
Total	420	1,650	105	......	......	......	....	115	......	......	......	......	....	120 39
Average	......	......	......	16	......	......	....	......	......	......	......	7.8	30.4	......

TABLE 2.—*Record of pile-driver.*

HOPEFIELD BEND.

Date when driven.	Number of piles.	Average length.	Total piling used.	Average penetration.	Number strokes of hammer.	Fall at last stroke.	Penetration at last stroke.	Remarks.
[illegible]		*Feet.*	*Feet.*	*Feet.*		*Feet.*	*Inches.*	
Aug. 11-20	16	32.6	871	13.7	......	......	......	180 feet have been used for 3 piles at Memphis.
21-31	95	34.0	4,853	14.0	25	25	2.5	
Sept. 1-10	82	33.1	3,860	12.2	29	21	1.4	
11-20	86	37.3	4,631	17.5	38	16	1.9	Driven with jet.
21-30	63	53.6	3,349	16.9	43	24	0.9	180 feet have been used for 3 piles at Memphis.
Total	344	......	17,564	......	......	......	......	
Average	......	38.1	......	14.9	34	21.5	1.7	

TABLE 3.—*Construction of mattresses, Memphis Harbor.*

Mattresses made. Date.	Mattresses made. Size.	Mattresses sunk. Date.	Mattresses sunk. Size.	Mattresses lost in sinking. Date.	Mattresses lost in sinking. Size.
1884.	*Feet.*	1884.	*Feet.*	[illegible]	*Feet.*
July 20-31	200 by 144	......	......	......	......
Aug. 1-10	378 by 144	Aug. 5	289 by 144	......	......
1-10	183 by 144	Aug. 9	472 by 144	......	......
11-20	457 by 300	......	......	......	......
11-20	600 by 150	......	......	......	......
21-31	223 by 300	Aug. 22	600 by 150	......	......
21-31	465 by 150	Aug. 26	365 by 300	Aug. 26	225 by 300
21-31	106 by 250	Aug. 26	300 by 100	......	......
		Aug. 29	425 by 150	......	......
Sept. 1-10	1,149 by 150	Sept. 6	240 by 250	Sept. 6	289 by 250
1-10	373 by 250	......	......	......	......
11-20	576 by 150	Sept. 11	850 by 150	......	......
11-20	......	Sept. 11	875 by 150	......	......
21-30	652 by 150	Sept. 26	908 by 150	......	......
Total squares	9,528.8		7,827.8		1,272.5

TABLE 4.—*Construction of mattresses, Hopefield Bend.*

Mattresses made.		Mattresses sunk.		Mattresses lost in sinking.	
Date.	Size.	Date.	Size.	Date.	Size.
1883.	*Feet.*	1883.	*Feet.*	1883.	*Feet.*
Nov. 1-10	837 by 140	Nov. 6	991 by 140	....	....
11-20	1,100 by 140	Nov. 20	1,561 by 140	....	....
21-30	1,057 by 140	....	....	Nov. 21-30	1,057 by 140
Dec. 1-10	862 by 140	Dec. 5	386 by 140	....	....
11-20	802 by 140	Dec. 20	790 by 140	....	....
21-31	700 by 140	Dec. 24	767 by 140	....	....
	....	Dec. 27	190 by 140	....	....
	....	Dec. 31	210 by 140	....	....
1884.		1884.		1884.	
Jan. 1-10	181 by 140	....	....	Jan. 1-10	203 by 140
Sept. 11-20	770 by 150	....	....	....	....
21-30	508 by 150	Sept. 27	1,115 by 150	....	....
Total squares	9,671.6		8,525.5		1,764.0

TABLE 5.—*Monthly expenses of work, November 1, 1883, to October 1, 1884, Memphis Reach and Harbor.*

Items.	November, 1883.	December, 1883.	January, 1884.	February, 1884.	March, 1884.	April, 1884.	May, 1884.	June, 1884.	July, 1884.	August, 1884.	September, 1884.	Total.	Total.
Office and fleet	$2,420 04	$1,369 84	$1,869 07	$1,367 06	$1,161 65	$1,060 02	$1,066 84	$2,977 01	$2,045 74	$2,550 38	$1,418 63	$19,306 28	$19,306 28
Steamer H. M. Graham	1,518 78	1,271 73	474 10	435 00	900 51	500 51	741 57	1,572 72	1,347 33	841 62	1,052 56	10,659 43	
Steam-launch Daphne	242 94	239 32	227 39	154 04	167 48	165 96	188 70	338 47	175 50	189 44		2,089 24	
Steam-tug Ida Patton									125 00	941 17	916 20	1,982 37	
Steam-tug Clarence		146 80	537 77									684 57	15,415 61
Survey							207 89	498 81	523 21	384 55	416 10	2,030 06	2,030 06
Repairs to plant and machinery	546 74	530 92	266 25	265 29	145 18	885 63	893 15	2,297 11	2,169 66	3,153 34	3,470 00	14,623 27	14,623 27
Mattressing Hopefield Bend	20,746 44	15,297 75	2,413 90							2,540 92	9,645 52	50,644 53	
Grading Hopefield Bend	829 49	499 25								375 24	905 14	2,609 12	
Clearing bank Hopefield Bend										120 30	235 15	355 45	
Pile driving Hopfield Bend										667 18	1,110 17	1,777 35	
Snagging Hopefield Bend	94 50								272 87	444 78		811 65	56,198 10
Mattressing Memphis Harbor									1,425 99	16,040 08	18,330 26	35,796 33	
Grading Memphis Harbor											2,457 06	2,457 06	
Draining Memphis Harbor											230 85	230 85	
Hauling bark Memphis Harbor											157 38	157 38	
Removing piles, Memphis Harbor											452 50	452 50	39,094 12
General service, coaling steamers	81 00	133 90	187 50								149 88	502 28	502 28
Total	26,479 98	19,489 51	5,925 98	2,221 89	2,374 82	2,612 12	8,100 65	7,684 12	8,084 80	28,249 00	40,947 40	147,169 72	147,169 72

TABLE 6.—*Itemized statement of expenses, November 1, 1883, to October 1, 1884, Memphis Reach and Harbor.*

Items.	General service.		General expense.							Revetment.				Total.	
	Coaling steamers.		Office and fleet.		Towing.		Survey.	Construction and repair of plant and machinery.		Memphis Harbor.		Hopefield Bend.			
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Pay-roll		$22 83		$12,976 62		$4,690 20	$1,588 50		$7,762 88		$13,950 11		$14,852 85		$55,843 99
Subsistence		2 82		3,671 12		1,425 92	424 34		1,687 69		3,720 45		6,487 37		17,419 71
Brush ......cords										7,261	9,656 29	10,619	18,406 05	17,870	28,062 34
Stone ......cubic yards			588.8	788 88						7,403	4,760 96	6,336	11,468 40	13,739	17,027 21
Iron ......pounds								2,839	93 94	39,760	1,479 56			42,599	1,573 40
Piling ......linear feet												17,352	1,145 43	17,352	1,145 43
Poles ......cords										495	800 85	352	560 70	847	1,361 55
Wire ......pounds										55,694	2,561 83	37,052	1,837 22	92,746	4,399 05
Spikes ......kegs										160	762 75	42	320 95	202	1,083 70
Wire rope ......linear feet										10,000	568 83			10,000	568 83
Lumber ......B. M. feet								121,017	2,787 03					121,017	2,787 03
Coal ......bushels	4,165	476 63	5,118	705 06	17,335	1,990 16		1,223	109 90			1,634	182 60	28,375	3,464 35
Hire of teams											157 38				157 38
Hire of tow-boat and tug				676 00		6,253 00									6,929 00
Diver (removing piles)											452 50				452 50
Miscellaneous				488 60		1,056 33	17 22		2,181 93		213 61		936 53		4,894 22
Total		502 28		19,306 28		15,415 61	2,030 06		14,623 27		39,094 12		56,198 10		147,169 72

Very respectfully, your obedient servant,

W. M. REES,
United States Assistant Engineer.

Capt. C. B. SEARS,
Corps of Engineers, U. S. A.

APPENDIX H.

REPORT OF CAPTAIN CLINTON B. SEARS, CORPS OF ENGINEERS, UPON OPERATIONS IN THE THIRD DISTRICT.

(Capt. W. L. Marshall, Corps of Engineers, U. S. A., in charge to April 21, 1884; Capt. C. B. Sears, Corps of Engineers, U. S. A., in charge since April 21, 1884.)

I.—LAKE PROVIDENCE REACH.

The extent of this reach, its physical characteristics, and the general project for its improvement, were fully set forth in the last annual report of Capt. W. L. Marshall, Corps of Engineers, and published in the Commission's Report for 1883. The work of the year has been a continuation of the work previously started, and has been carried on by similar means and with the organization then obtaining.

(1.) *Duncansby to Stack Island.*

Assistant Engineer Arthur Hider, in immediate local charge, assisted by Assistant Engineer Childs, in charge of mattress and revetment work; Assistant Engineers Ruple and Tollinger, in charge of dike work; and Assistant Engineer Thompson, in charge of surveys and observations.

DUNCANSBY SYSTEM.

The additional dike on Range 36, under way at last report, has been finished, and some repairs have been made in the main dike near the head, joining the outer ends of Cross-dikes 6 and 7, and gaps in these cross-dikes have been closed.

The channel continues to encroach upon the dikes at the upper end, and will probably continue to do so until the revetment of Pilcher's Point Bend shall have been completed. No further work is recommended here, except such repairs as circumstances may dictate from time to time, to avert the river going down through Skipwith Chute, should such danger threaten.

MAYERSVILLE SYSTEM.

Cottonwood dikes.—This is new work, and has been constructed during the past season. It is shown on the progress sketch. Its object is to contract the channel way, regularize the channel, and hold it in the bend of Mayersville Island (No. 93).

A new feature in these dikes is a parallel interior longitudinal dike in addition to the usual cross-dikes. Their construction has resulted in a considerable fill below and behind them, thus building up the bar and keeping the channel on the other side. The whole of the work is in good condition, and is the most compact and symmetrical piece of dike work on the reach.

DIKES IN MAYERSVILLE CHUTE.

The object of the work here is to close the chute behind Mayersville Island (No. 93). The five-row cross-dike finished last fall stood through the flood of 1884 until April 21, when a gap some 125 feet in width took place. This gap has since been closed.

The channel is encroaching on the head of these dikes, and has carried away all but 600 feet of the longitudinal dike. This will result in no material injuries to the system if the chute can be closed and the head of the island held. It is proposed to bring this about by more cross-dikes below the present one, and by extra mattressing round the head of the island.

REVETMENT OF MAYERSVILLE ISLAND.

The work here has consisted in the repair, extension, and strengthening of the work of last year. The island is all sand, and the current along its front is strong.

Most of the revetment has stood reasonably well, considering these facts. Whether the head of the island will hold against the encroachments of the main channel is problematical. If it does it will be a satisfactory test of the efficacy of this mode of revetment, though at best it will always need watching and immediate and frequent repairs. In this connection attention is called to Assistant Engineer Childs's subreport, marked Appendix H 3.

BALESHED SYSTEM.

The laying of foot-mats at the head of the system was finished last winter before high water.

During the season just past a high-water dike has been built in rear of the main (low-water) dike from Cross-dike 1 to 4, and extended down outside of main dike to Cross-dike 6.

A cross-dike from the Mississippi shore to the main dike at a point about 2,000 feet above Stack Island has been built, and the main dike from this point to the island has been re-enforced by an interior longitudinal dike.

In addition some repairs have been made in Cross-dikes 3 and 4 and the main dike between Cross-dikes 5 and 6 has been strengthened by sinking condemned barges in front.

The Baleshed system shuts off a long, continuous line of chute. The head of the system is now essentially dry at half stage. The first depression occurs at Cross-dike No. 5. From here to the foot of Stack Island is 4½ miles, representing a fall of about 16 inches; that is, were the pool behind the dike at No. 5 at the same level as at the foot of Stack Island, the water pushing through the dike would have a straight drop of 16 inches.

The steep slope of the water surface gives high velocity, and this has caused trouble at this point. It is proposed to break up this fall by two or more cross-dikes, thus making a series of pools. For further details, see reports of Assistant Engineers Hider, Childs, Ruple, Tollinger, Thompson, and Steubing, herewith, marked Appendices H, H 3, H 4, H 5, H 6, H 8.

(2.) *Pilcher's Point (Louisiana) Bend.*

Assistant Engineer J. E. Turtle in local charge, assisted by Assistant Engineer H. Steubing.

The work of upper and lower bank revetment in this bend has been pushed rapidly since the fall of the water, and there is every prospect of finishing the greater portion before the next rise. The lower bank revetment at the upper end, put in last November and December, was found to be in good shape this season, and no caving took place.

The part revetted at the middle of the bend, as might be expected, was flanked from above and caving took place behind it. As far as can be ascertained by a diver, this revetment is intact and lying on the bottom of the river in the same vertical prism of projection as first placed. It has simply assumed a horizontal position. Efforts will be made to lap on to this with the new work. It is a reasonable supposition that had this mat been protected at the upper end, and the upper bank been revetted, the caving would not have occurred.

For further details of this work, see the report of Assistant Engineer Turtle herewith, marked Appendix H 2. The map herewith, marked Appendix H, Plate VII, will show the progress of the work.

FINANCIAL STATEMENT.

Lake Providence Reach.

Balance available November 1, 1883	$156,327 93
Additional allotment from unallotted reserve	67,200 00
Amount transferred from Vicksburg Harbor allotment	42,295 00
Amount allotted from appropriation of January 19, 1884	400,000 00
Amount allotted from appropriation of July 5, 1884	300,000 00
	965,822 93
Expended from November 1, 1883, to September 30, 1884:	
Services	223,366 21
Material and supplies	213,807 18
Subsistence	50,430 20
Plant, tools, and repairs of same	65,269 00
Charter of steamers, barges, &c	9,305 00
Fuel	28,623 80
Miscellaneous	25,223 88
General service	18,711 41
Total expended	634,736 68
Transferred to levees, Yazoo and Tensas fronts, $10,000 each	20,000 00
Transferred to levees, fourth district	27,000 00
Transferred to general service	10,000 00
Amount paid R. Moore on account of dredging in Vicksburg Harbor	10,593 58
	702,330 26
Balance available October 1, 1884	263,492 67
Balance in Treasury	200,000 00
Balance in hands of Captain Sears	63,492 67
	263,492 67

(3.) *Summary.*

The original condition of the channel-way along the Lake Providence Reach was bad, the channel being flat, badly defined, and often with only 5 feet of water.

The original project for improvement was the narrowing of the waterway to 3,000 feet by closing the chutes and creating artificial banks through deposition, and the preservation of the natural curves of the river by revetting the caving banks.

No important amendments, alterations, or additions have been made in the general plan. Some details of construction have been changed from time to time as experience demanded.

The total amount expended to November 1, 1883, was $1,228,916.47. At that date the availability for the purposes of navigation and commerce of the channel had been greatly improved, there being throughout the reach a depth not less than 12 feet, with a fair navigable width.

During the eleven months from November 1, 1883, to October 1, 1884, there have been expended $634,736.68, and the channel-way has shown a betterment in the regularity of outline, in width and depth, there having been no water less than 15 feet along the channel-way, though less depths have been reported by commercial steamers; they were, however, not in the deepest portion of the channel, either through accident or by reason of there being sufficient water for the boats on the line traversed, hence no need to follow the line of deepest water.

There has been throughout the low-water season, to date, a deeper channel by from 6 to 7 feet than has obtained on the river for 40 miles above the Lake Providence Reach.

The works generally have stood the last flood very fairly, the damages that have occurred having been due to local causes.

No extended caving has occurred as yet where the bank revetment has been completed in good shape.

During the year ending October 1, 1885, $400,000 can be profitably expended towards carrying out the project for the improvement of this reach. With this it is proposed to revet some 25,500 linear feet of bank, at four places, viz:

	Feet.
Miss. R. 30 to R. 34	7,500
Miss. R. 44½ to R. 49	9,000
La. R. 72 to R. 74	3,500
La. R. 86 to R. 89	5,500
Total	25,500

To build in Mayersville and Baleshed chutes 3,000 linear feet of dike, to wattle dikes already constructed, to repair existing dikes and revetment, to repair plant, and to pay for transportation, administration, and surveys.

The advantages and benefits to be expected therefrom are the continuation of the project adopted by the Commission, and the maintenance of the present good low-water channel.

An estimate for the entire and permanent completion of the work of improvement on this reach I am unable to give, not knowing the intentions of the Commission to the ultimate extent of the work.

As this work is only one link in the chain of general improvement of the river, the amount of commerce and navigation that will be benefited is that incident to the whole river, a statement of which has already appeared in the previous reports of the Commission.

The present estimated value of the plant, tools, and outfit on hand, belonging to the reach, is $300,000.

II.—VICKSBURG HARBOR.

(Assistant Engineer H. St. L. Coppée, in local charge.)

The work here consists of the improvement of the harbor proper and the maintenance of Delta Point, in Louisiana, opposite Vicksburg.

The former is entirely local in character, and would add nothing to the general improvement of the river.

No funds were allotted from the last two appropriations, and no work has been done except a survey in June, 1884. This showed a tendency of the channel above the town of Vicksburg to cut into the bar across the mouth of Centennial Lake, and that the basin partly dredged in 1883 has remained practically unchanged.

DELTA POINT, LOUISIANA.

The holding of this point is deemed essential to prevent further recession of the river from Vicksburg and to maintain the regimen of the river immediately below. The point has been held by brush and stone revetment against a fierce current for two years, but at great expense for repairs and enlargement. There is no reason to suppose that extensive repairs will not be necessary annually unless the river, due to changes in the curvature above, changes over so as to leave this point in slackwater.

In January last an attempt was made to repair the revetment, but work was stopped by a rapidly rising river before much had been done.

Early in August, with plant borrowed from the Lake Providence Reach, work was resumed and pushed as vigorously as the climate and class of labor available would permit. It consisted of extensive repairs to the upper and lower bank revetment at the upper end, and of a continuation of the same at the lower end. It was finished October 10, 1884, and the plant returned to the Lake Providence Reach. For further details attention is called to the report of Assistant Engineer Coppee, herewith, and two drawings, marked Appendix H 9, Plates X, XI, respectively.

The total expenditure on Vicksburg Harbor under the Commission, to date, has been $147,754.44, and of this about $100,000 has been expended on Delta Point. Previous to the Commission taking charge, $203,229.87 had been expended on Delta Point.

If the revetment holds all right during the coming year no money will be needed for this improvement, but as it is probable that weak places will develop, it is thought that it will be advisable to have $10,000 available for possible repairs.

FINANCIAL STATEMENT.

Vicksburg Harbor.

Balance available November 1, 1883		$55,477 60
Balance available from Delta Point allotment		7 64
Amount allotted from appropriations of July 5, 1884		25,000 00
Total		80,485 24
Expended from November 1, 1883, to September 30, 1884:		
Services	$12,746 47	
Material and supplies	5,770 18	
Subsistence	2,439 10	
Plant, tools, and repairs of same	299 38	
Charter of steamers, barges, &c	645 19	
Fuel	829 10	
Dredging (retained percentage)	4,235 41	
Miscellaneous	504 72	
Total expended	27,469 55	
Transferred to Lake Providence Reach allotment	42,295 00	
		69,764 55
Balance available October 1, 1884		10,720 69
Balance in hands of Captain Sears		10,720 69

LEVEES.

The unfinished contracts for levees on Yazoo Front were completed in December, 1883. During the last flood none of the levees on this front built or repaired by the United States gave way, but they were damaged by wave-wash to the amount of $40,000 and were only held by the energetic exertions of Captain Marshall, aided by the local inhabitants. About $11,000 were expended in protecting them with planks and sand-bags, and in raising them in the face of the flood. About 23,000 sacks and 10,000 feet of lumber were used.

The same exertions on the Tensas Front saved many miles of levee, but were not so entirely successful in averting breaks. A number of breaks took place from Delta to Bedford, one break at Raleigh, and considerable damage from wave wash. The amount expended for protection on this front was about $18,000. Over 47,000 sacks and 23,100 feet of lumber were used.

The Commission at its last meeting made an allotment of $160,000 for the general repair of United States levees in the second, third, and fourth districts, to be divided by the United States Board of District Officers. Besides this, it allotted $25,000 for the levee from Arkansas City to Amos Bayou, provided sufficient means should be guaranteed by the local authorities to complete this levee. Up to date this guarantee has not been given.

The United States Board of District Officers allotted of the $160,000, $90,000 to the Tensas Front, fourth district, $50,000 to the Tensas Front, third district, and $20,000 to the repair of levees on the Yazoo Front, second district, providing the local levee board, on or before September 10, guaranteed to expend $500,000; in default of this, the $20,000 was to go to the repair of levees on the Yazoo Front, third district.

This guarantee not having been given by September 10, this sum reverted as indicated, and steps were taken in the latter part of September to provide for its expenditure.

September 5, advertisements for repairing gaps at Raleigh and Delta, La., were published. The bids were opened September 15, and the contract for both pieces was awarded to George Arnold, the lowest of fifteen bidders, at 17¾ cents per cubic yard for the Raleigh work, and 18¾ cents per cubic yard for the Delta work. Work was begun immediately and is now progressing.

FINANCIAL STATEMENT.

Levees—Yazoo Front.

Balance available November 1, 1883		$20,213 68
Transferred from allotment for protection of cut-off at Tarpley's Neck		3,000 00
Transferred from Lake Providence Reach		10,000 00
Allotted appropriation of July 5, 1884		20,000 00
Total		53,213 68
Expended from November 1, 1883, to September 30, 1884:		
Services	$3,278 53	
Labor and material, protection of levees	12,190 75	
Subsistence	41 84	
Plant, tools, &c	17 00	
Contractors, estimates	13,633 21	
Miscellaneous	449 10	
		29,619 43
Balance available October 1, 1884		23,594 25
In Treasury		20,000 00
In hands of Captain Sears		3,594 25
Total		23,594 25

Leveees—Tensas Front.

Balance available November 1, 1883		$57,683 51
Amount allotted, appropriation of January 19, 1884		10,000 00
Amount transferred from Lake Providence Reach allotment		10,000 00
Amount allotted, appropriation of July 5, 1884		50,000 00
Amount deposited by Captain Marshall on account of error in his accounts		1 50
Total		127,685 01
Expended from November 1, 1883, to September 20, 1884:		
Services	$5,383 42	
Labor and material, protection of levees	16,935 35	
Subsistence	161 50	
Plant, tools, &c	74 60	
Contractor, estimates	47,358 47	
Miscellaneous	585 20	
		70,498 54
Balance available October 1, 1884		57,186 47
In Treasury		50,000 00
In hands of Captain Sears		7,186 47
Total		57,186 47

The following drawings accompany this report:

LAKE PROVIDENCE REACH.

One map showing velocity and discharge-section curves, marked Appendix H, Plate III.

One tracing showing changes in discharge section, marked Appendix H, Plate IV.
Three tracings, Plates VII, VIII, IX, showing condition of works October 1, 1884, marked Appendix H.
One tracing of comparative sections, Pilcher's Point, marked Appendix H, Plate VI.
One tracing of comparative sections in chutes, marked Appendix H, Plate V.
One tracing July quarterly survey, $\frac{1}{10000}$ scale, marked Appendix H, Plate I.
One map discharge curves, area, velocity, and discharge, marked Appendix H, 'late II.

VICKSBURG HARBOR.

One tracing showing Vicksburg Harbor and Delta Point, marked Appendix H, 'late X.
One tracing showing details of work at Delta Point, mark ed Appendix H, Plate XI.

Respectfully submitted.

CLINTON B. SEARS,
Captain Engineers, U. S. A.

H 1.

EPORT OF ARTHUR HIDER, ASSISTANT ENGINEER, UPON OPERATIONS LAKE PROVIDENCE CONSTRUCTION PARTY.

WILSON'S POINT, LA., *October* 1, 1884.

SIR: The following report of the operations of the Lake Providence construction arty, from November 1, 1883, to October 1, 1884 (eleven months), is respectfully subaitted:

The portion of the river known as the Lake Providence Reach extends from Carlina to Hays' Landing, Miss., a distance of about 35 miles. The crossings on the ower portion of the reach, between Island 93 and Island 95, have heretofore been roublesome, on account of shallow water, during the low stages of the river; in fact, his part of the reach of late years has been considered, at low water, the shoalest art of the river between Plum Point and New Orleans.

The depths on some of the crossings, in former years, have been not more than 5 eet, with a very narrow channel, rendering navigation for boats of large size imracticable during the low-water period.

The original project for the improvement was, the contraction of the river at exessively wide places, the revetting of caving banks, and closing the island chutes.

The work now in progress and that which has been completed has been revetting he Louisiana Bend and the front of Mayersville Island with mattresses; closing the Duncansby, Mayersville, Baleshed, and Stack Island chutes by a system of pile ikes; and the construction of a system of dikes on Cottonwood Bar, to contract the vidth of the river at that point.

The effect of the work that has been finished is shown in an increased depth of vater on all crossings which were heretofore shoal during the low stages of the river.

The least depth of water found at any point in a channel 1,000 feet wide, from Elton o Stack Island, was, August 30, 10 feet; this increased to 14 feet September 9, and September 30 the depth was 15 feet. Below is given the least depths found in a channel 1,000 feet wide, on the Stack Island Crossing; also the least depths on the crossing rom Ben Lomond to △ Wiley, with dates and gauge-readings at Lake Providence. There has been at all times a channel for steamboats on the Stack Island Crossing as usually run by them of at least 15 feet in depth. The depths as given in the table are the *least* depths found in a channel 1,000 feet wide on the crossing.

Shallow Crossings, Lake Providence Reach.

Date.	Lake Providence gauge-reading.	Stack Island, 1,000-foot channel. Least depth.	Ben Lomond, 1,000-foot channel. Least depth.
1884.		*Feet.*	*Feet.*
August 9	15.5	18	24
August 19	12.6	14	12
August 30	8.9	10	14
September 9	9.1	14	17
September 19	6.6	17	11
September 30	5.8	15	11

Ben Lomond Crossing is about 3 miles below the head of Stack Island. The lowest point where improvement works have been constructed is at the head of Stack Island. During the present low-water season there has been no difficulty experienced by steamboats in navigating any part of the reach.

For the same period covered by the soundings as given above, the least depths in steamboat channel on the Sterling Crossing, 4 miles, and Leland, 35 miles above Carolina Landing (the beginning of Lake Providence Reach) were as follows:

Crossings above Lake Providence Reach.

Date.	Lake Providence gauge-reading.	Sterling (4 miles above reach).	Leland (35 miles above reach).
1884.		*Feet.*	*Feet.*
August 8	15.5	8	9
August 20	12.0	8½	8½
September 1	8.5	9	8½
September 11	9.8	9	8
September 13	8.9	9	8
September 27	5.7	9	7

This shows a marked improvement in the channel depths on the reach, at the shoal places, compared with that found in the river immediately above.

The amount expended for labor on the improvement from Duncansby to Stack Island is given below in the following statement:

Cost of labor and subsistence.

	Pay-roll.	Subsistence.	Total.
Mattress construction and bank protection	$44,915 09	$10,956 93	$55,872 02
Dike construction	40,678 63	9,993 66	50,667 29
Surveys	10,347 15	2,006 54	12,353 69
Tow-boat service	19,951 84	3,379 59	23,331 43
Construction and repairs to plant, &c	34,579 15	4,813 72	39,392 87
Care of property	6,914 14	2,215 17	9,129 31
Total	157,381 00	33,365 61	190,746 61

The average cost of a ration, including ice in the warm months, has been—

	Cents.
Cost of raw material	29.6
Cost of ration served	37.3
Cost of ration for each day's labor secured	43.3

The maximum number of men employed in any one month has been 716; the minimum, 111.

During the next year the following amount, to continue the improvement as laid out in the original project, can be profitably expended in revetting caving banks and in dike constructions:

Bank protection to prevent caving.

	Linear feet.
From R. 30 to R. 34, Mississippi	7,500
From R. 44½ to R. 49, Mississippi	9,000
From R. 72 to R. 74, Louisiana	3,500
From R. 86 to R. 89, Louisiana	5,500
Total	25,500

25,500 linear feet, at $10.12	$258,060
Pile dikes, Mayersville and Baleshed chutes:	
3,000 linear feet, at $7.25	$21,750
Wattling dikes already constructed at Baleshed and Stack Island	5,000
Repairs to dikes and revetment	15,000
Tow-boat service	25,000
Repairs to plant	40,000
Care of property	10,000
Contingencies	5,190
Total amount that can be profitably expended	380,000

The construction of mattresses and revetting of caving banks has been under the direction of Assistant Engineer William M. Childs, the dike work under Assistant Engineers C. P. Ruple and E. C. Tollinger. Assistant Engineer Henry Steubing had charge of unloading stone and distributing same on revetment of Mayersville Island, and, for a short time, was engaged in foot-mat construction. On August 1 he was transferred to the work at Pilcher's Point.

The surveys made have been under Assistant Engineer E. D. Thompson.

Reports showing in detail the work done by each assistant are transmitted.

At the close of last season the following work was in progress, viz:

The construction of an additional dike at the head of Duncansby system; revetting the face of Mayersville Island; completing foot-mats, &c., at the head of the Baleshed system of dikes.

This work was all completed before the high water, with the exception of a portion of the mattress-work near the lower end of Mayersville Island.

The work done during the present season has been: The construction of the Cottonwood system of dikes; the building of a high-water dike in rear of Baleshed main dike, from Cross-dike 1 to 4, and extending same on outside of main dike to Cross-dike C; the construction of a cross-dike across Baleshed Chute, above the head of Stack Island, from the Mississippi shore to the Stack Island main dike, and thence to the head of Stack Island; repairing damages to dikes from the flood; building dike from the outer end of Dike 6 to 7, Duncansby system; repairing revetment on Mayersville Island, and covering the upper revetment with additional stone. For location of dike, &c, see sketches 1 and 2 herewith.

EFFECT OF THE LAST FLOOD ON THE CONSTRUCTION WORKS.

The dike-work generally withstood the flood with but comparatively little damage. The principal injury done was to the dikes at the upper end of the old Duncansby Tow-head; the outer ends of the cross-dikes above No. 7 were cut off during the high water; the upper Duncansby Tow-head has entirely disappeared; the steamboat channel is now where the tow-head was the previous season.

This damage is due to the rapid caving of the banks in the Louisiana Bend forcing the main channel of the river to the Mississippi side below Pilcher's Point. The channel is now along this shore to the head of the Duncansby Dikes, at which point it again crosses back to the Louisiana side.

The current thus forced against these dikes has had the effect of undermining them at their outer ends, and of caving away the tow-head, which was of sand and unprotected. The encroachment of the channel upon the bar at the upper end of the Duncansby Chute will continue until the bend above Pilcher's Point is prevented from further caving by the revetment work now in progress there.

Gaps were broken in Dikes 6, 7, 8 in Duncansby Chute during the high water. The gaps in each of these dikes were about 100 feet in width. The breaks were in the deepest water of the chute.

The low-water dike constructed in 1882, from Wilderness Landing to the head of Mayersville Island, was scoured out during the flood, except about 600 feet nearest the Mississippi shore, which remain intact. This undermining was due to the deep-water channel working in towards the head of the island.

The cross-dike in Mayersville Chute stood during the high water of February, March, and part of April. A gap about 125 feet in width occurred April 21, releasing a part of the large drift accumulation which had lodged in front of the dike. The effect shown immediately afterwards was the washing out of a hole 20 feet in depth through the gap.

The chute is now nearly dry in the vicinity of the dike, and the effect on the bottom is noticeable immediately at the break, and for about 800 feet below, where a deep hole has been scoured out.

The only assignable reason for the failure of this dike seems to have been from the pressure of drift in front; the drift, not extending to the bottom, caused a scour at the foot of the piles and weakened the dike, which was then unable to withstand the pressure from the front and gave way.

At Baleshed, the only breaks that took place were in Cross-dikes 4 and 5, in which gaps of about 200 feet in width occurred. The upper of these dikes had considerable drift in front of it and is in an exposed situation when the water is over the 20-foot stage, being located immediately below where the low-water and high-water main dikes join.

The above comprises all the damage done to dike-work by the last flood; about 18¼ per cent. of the dike-work constructed previous to November 1, 1883, was washed out.

At Duncansby and Wilderness the dikes gave way by undermining, caused by encroachments of the deep-water channel.

In Duncansby, Mayersville, and Baleshed chutes the breaks were due to drift.

The revetment work on Mayersville Island withstood the effect of the flood, with

the exception of two slides in the revetment near the head of the island, and about 5,210 feet at the lower end, where the bank is low; at this point the river cut behind the revetment, and it caved in.

The damage occurred to the work at the upper end of the island immediately after the flood, while the river was falling rapidly; at the lower end of the island the injury was done during the flood; nearly 27 per cent. of the work done during the season on the island washed out during the high water.

Duncansby Dikes, present condition of the improvements.—The damage to the dikes at the head of the Duncansby system still continues and will, in all probability, not cease until the river at this point adjusts itself to the conditions above, and assumes a more symmetrical shape.

The gaps in the chute in Cross-dikes 6 and 7 have been closed, and a dike driven joining the outer ends of 7 and 8. From present indications it is probable that the river will cut the outer ends of 7 and 8 still further back, as the channel is now working in that direction, and there is a strong current thrown against this part of the work.

Mayersville Dikes.—The gap in Cross-dike 1 has been repaired. This dike will need strengthening to stand the next high water. The deflecting dike built in 1882 at the head of the chute was washed out during the flood.

Cottonwood Dikes.—These dikes are all in good condition.

Baleshed Dikes.—The gap in the main dike, which occurred while the stage of the river was about 10 feet below high water, as well as the gaps in the Cross-dikes 3 and 4, which occurred during the flood, have been repaired; this system of dikes is now in good condition.

Stack Island Dikes.—The dikes here are all intact.

Elton Dikes.—The outer ends of these dikes have been cut off during the flood; but not before they had served the purpose for which they were originally constructed. For location, &c., of dikes, see sketches herewith.

Mayersville Island.—The work from the head of the island to a point 8,300 feet below is in good condition, except about 1,200 feet next to the head, where the mat is broken in a few places next the bank.

Slides in the revetment have taken place; this will require about 1,000 feet of new work from the head of the island down.

METHODS OF CONSTRUCTION.

No material changes in the method of construction have been made during the present season from that in practice heretofore, described in the report of last year's operations.

In the construction of dikes, instead of cottonwood braces, two cypress planks 3 by 8 inches, one fastened on each side of the pile, with an abutting piece mortised into the plank, have been used to a great extent. These are more rapidly put in place, and although the first cost is somewhat greater, it is believed that the saving of time more than compensates for the additional cost, besides giving a better brace.

The use of cypress for the construction of dikes is recommended both for piles and braces; cottonwood will last but two or three seasons, when exposed, while the life of cypress is much greater and will allow of much more satisfactory work being done.

A steam hammer has been tried for driving piles, which gave quite satisfactory results. The leads of the driver upon which it was used have been lengthened, so as to give it further trial. We were able to drive piles from 5 to 8 feet, after the limit of penetration had been reached with the ordinary drivers and with comparatively little battering of the heads.

The practice in mattress construction has been to make them continuous, joining the grillage laid on the slope of the bank with the mattress before sinking, so as to make the construction continuous from the top of the bank to the outer edge of the mattress.

Before sinking, the flotation of the mattress is nearly destroyed by ballasting it with stone distributed over the surface; it is then sunk in position, beginning at the head and retaining the lower end of the mattress on the weaving barge, so that sinking and building mattress can proceed at the same time.

No loss of mattress occurred this season while sinking.

The experience of last year shows that where damage has occurred to mattress-work it has generally been by sliding of the bank. The lower part of the slope just below the low-water line is the point that first gives way, in many instances the mattress tearing apart from the bank revetment proper, leaving a space at the foot of the bank slope exposed without protection to the eroding action of the current.

It would appear that a stronger form of revetment than that afforded by the ordi- brush construction used heretofore will be required to connect the subaqueous s with the revetment laid on the slope of the bank in order to insure satis- results.

Below is a list of the floating property constituting the plant:

st of boats, barges, pile-drivers, &c., constituting the plant belonging to the reach, of which five small barges, 75 by 15 feet, and one, 65 by 15 feet, were built on the works.

Classification.	No.	Dimensions.	Remarks.
		Feet.	
w-boats	5	....	1 chartered.
aders	2	110 by 30	
ttress-boats	4	160 30	
Do	1	140 49	
een-boats	4	100 25	
arter-boats	10	130 25	
Do	1	100 30	
Do	1	135 30	
Do	2	100 25	
Do	2	80 20	
Do	1	70 18	
chine-shop boat	1	100 25	
rpenter-shop boat	1	211 25	
mber-boat	1	211 35	
ck	1	186 56	
Do	1	37 16	
Do	1	25 8	
harf-boat	1	186 26	
rrick-boat	1	100 24	
mp-boat	1	47 12	Steam.
rge, decked	1	132 24	Model.
Do	2	160 28	
Do	8	120 26	Flush.
Do	28	100 25	Do.
Do	5	75 15	Do.
Do	1	66 15	Do.
Do	1	60 14	Do.
le-drivers	12	70 20	
Do	4	82 20	
tamaran	1	....	
lking flats	8	25 7	
Do	2	42 12	
wls	3	....	
iffs	65	....	
Total	183	....	

MMARY OF WORK COMPLETED AND MATERIAL EXPENDED FROM NOVEMBER 1, 1883, TO OCTOBER 1, 1884.

Work done.

imber of piles driven		9,292
imber of stringers put in place		3,601
imber of braces put in place		6,383
imber of linear feet of dike completed, 2 row		5,463
imber of linear feet of dike completed, 3 row		20,841
imber of linear feet of dike completed, 4 row		861
		27,165
rillage foot-mat built, 20,594 linear feet	squares	8,425
oven foot-mat built, 6,196 linear feet	do	4,164
attress built, 10,928 linear feet	do	13,786
evetment built, 15,528 linear feet	do	8,061
iore-mat, 2,175 linear feet	do	836
attling, 9,948 linear feet	do	796
ilted screens, 2,839 linear feet	do	1,039
ank graded, 8,731 linear feet	cubic yards	71,379
inear feet pile-dike standing November 1, 1883		44,235
inear feet pile-dike constructed present season		27,165
		71,400
educt old work washed out the present season		8,294
Amount pile-dike October 1, 1884		63,106

On Mayersville Island there is now in fair condition 7,130 linear feet of revetment and mattress work.

Material expended.

Piles	number..	9,559
Stringers	do....	3,471
Braces	do....	6,383
Stone	cubic yards..	30,350
Cottonwood poles	cords..	1,417
Brush	do....	24,737
Wire	pounds..	167,000
Iron and spikes	do....	178,463
White lead	do....	4,515
Oakum	do....	5,592
Lumber	feet, B. M..	275,200
Coal	bushels..	190,327
Sacks	number..	4,600

Very respectfully,

ARTHUR HIDER,
Assistant Engineer in charge.

Capt. CLINTON B. SEARS,
Corps of Engineers, U. S. A.

H 2.

REPORT OF J. E. TURTLE, ASSISTANT ENGINEER, UPON OPERATIONS AT PILCHER'S POINT.

UNITED STATES ENGINEER OFFICE,
Pilcher's Point, La., October 6, 1884.

SIR: The following report of operations of work done at Pilcher's Point, La., from November 1, 1883, to October 1, 1884, is respectfully submitted.

The object of the work at this point was to hold the present shore-line, thus preventing a deflection of the current to the Mississippi side below, which deflection was supposed would cause serious damage to the work at head of Duncansby Chute.

The plan adopted to hold the present shore-line was by woven willow mattresses, which are supposed to cover, when sunk, a sufficient amount of the slope to prevent erosion; and by upper bank revetment.

On November 1, 1883, there were employed at this point two mattress parties, one brush party, snag-boat O. G. Wagner, and tow-boat Pearl.

Owing to a scarcity of labor in summer of 1883 the work did not get well under headway until about November 1, 1883. On November 6, owing to a low condition of funds, Captain Marshall, U. S. A., issued instructions to drop mat construction as soon as practicable and transfer one of the mat parties to Island No. 93. The latter part of these instructions were carried into effect November 24.

On December 15 the upper mat party at this point was disbanded, and such of them retained as was necessary to store track lumber for winter.

On December 17 brush party was also transferred to Island No. 93, to assist in the completion of the work at that point before high water.

Party retained at Pilcher's Point was disbanded December 26, 1883. Parties on Island 93 disbanded, one on December 29, one on January 8, 1884.

Snag-boat O. G. Wagner continued work until 11 a. m., November 7, when a crack occurred in her boiler. On November 15 J. R. Meigs reported to take place of Wagner.

On November 30 Wagner was taken in tow by the steamer Mississippi and delivered to Major Miller.

Meigs continued work until December 18, when pulling snags was abandoned. On December 19 she departed for Memphis, to be delivered to Major Miller.

Tow-boat Pearl was employed until December 28. On December 29 she was taken in tow by steamer Mississippi, to be delivered to owners.

Quarter-boats and mat-barges were placed with the fleet at Wilson's Point, property checked and placed under lock and key.

On January 28 a small force was organized for the purpose of furnishing mattress poles and stringers to construction party at Wilson's Point. On February 11 water got over bank, and work was abandoned.

On April 7 a small force was again organized to supply braces and stringers to party at Wilson's Point. Timber was cut from skiffs and floated to barges. This work continued until May 27, then, owing to a falling river, was abandoned, and clearing caving banks of timber was begun. This latter work was continued until June 23, when mat construction commenced, and since that date has been pushed as rapidly as the class of labor and hot weather would permit.

The head of the mat work this season overlaps the lower end of mat sunk in 1883.

After an unsuccessful attempt to remove the snags from this bend—first with a pile-driver, and after with grader No. 3—a diver was procured, the object being to cut off the snags by means of dynamite. The cartridges used were half-pound Hercules powder, one or more being used as the size of snags demanded. Cartridges were tied against the snags, close to the bottom, and exploded with a battery. This means of removing snags proved a perfect success.

The diver (Mr. Howard) has examined the upper mat (1,690 feet in length) sunk in 1883, and all the mat sunk in 1884. The mat of 1883 was found to be in a good state of preservation, and to be well done on the bottom, the outer edge resting on a stratum of blue clay.

On the evening of September 19, a cave occurred which injured about 100 feet of the mat sunk in 1884. The slide is supposed to be caused by the grader, which was grading at the time at the point where the slide took place. With the exception of this 100 feet, the mat sunk in 1884 was found to be in good condition, the outer edge resting on a stratum of blue clay.

Grader No. 3 was received from Wilson's Point on the evening of July 31, and began grading on August 1. Much delay was occasioned at first by inexperienced labor—poor quality of hose (used last season), sickness of engineer, and a crack in pump chamber.

On September 15, grader No. 1 was received from Vicksburg, and put to work at once; since then a double crew has been employed, and good progress made. This work has been under the charge of Assistant Engineer H. Stenbing.

Carpenters have been employed overhauling mattress barges, quarter-boats, building addition to office, and in general repairs.

Blacksmith has been employed welding mat rods, and on general repairs.

The steamers Osceola and Etheridge have done the local work.

There has been an abundant supply of material.

DESCRIPTION OF WORK.

The mattresses employed here are the common woven mattress of willow, and have been explained in detail so often that explanation here is deemed unnecessary. The widths used are 180, 168, and 165 feet (these widths do not include grillage mat), and have been made continuous, the longest mat being 3,440 by 180 feet.

Previous to sinking, the mats have been well ballasted (flotation destroyed) their entire lengths, or over such lengths as were to be sunk from time to time. The head or up-stream ends are sunk first by pulling a barge loaded with rock over the mat, beginning about 250 feet below the head, and then towards it; when the head is reached it is loaded with sufficient rock to carry it rapidly to the bottom; the straps (from 12 to 16 in number) that anchor the mat to the mooring barge are let go simultaneously. The anchor lines that hold the mat to the shore are sunk with it, and by means of shackles and trip-lines, made fast to buoys, are released when a sufficient quantity of the mat is on the bottom to secure its safety.

Every 300 feet mats are made fast to shore by 2-inch manila lines (two lines abreast on the outer half of the mat); these lines are also sunk with the mat and treated as the head lines.

The upper bank revetment consists of courses of willow brush placed upon a framework of poles, and are held in place by cross poles firmly wired to frame-work underneath.

GENERAL REMARKS.

On June 1, 1884, it was found that the upper mat (1,690 feet in length) sunk in 1883, was still in place, no caving having occurred behind it; the lower mat (2,308 feet in length) was found to be gone.

A resurvey of the shore-line along this mat indicated the least caving to be 150 feet, the greatest 600 feet, it being greatest at the lower end. As this was a detached piece of work, situated at the worst point in the bend, other results could not be expected. It is deemed advisable not to revet the lower one-half or three-quarters of a mile of this bend, as it is hoped if this is left unprotected it will wash away during the high water, thereby materially assisting in carrying into effect the purpose of the work.

If the work done this season will be found in perfect condition after the high waters of 1885, the revetment of the above three-fourths of a mile will be all that remains to be done to finish the work at this point, requiring an expenditure of about $42,000.

The progress of the work has been greatly delayed by the shifting class of labor employed. The work at first is entirely new to them. As soon as they become acquainted with it they are ready to leave.

Number of laborers that commenced work in August and were paid off before the month closed, was 287; in September, 350.

I feel under obligations to the employés on the work for the faithful and untiring manner in which they have performed their duty, and to Assistant Engineer Arthur Hider for the prompt and agreeable manner in which he has responded to my requisitions for material and different pieces of his plant.

Appended hereto is summary of work done, material expended, and statements of cost of work.

Statement of cost of work done at Pilcher's Point, Lake Providence Reach, from November 1, 1883, to October 1, 1884.

Description.	Pay-roll.	Subsistence.*	Material.	Totals.
Mat and bank revetment	$37,002 25	$9,532 49	$63,751 29	$110,286 03
Snag-boat	1,678 95	383 13	163 50	2,225 58
Brush party	4,522 75	1,441 86	326 11	6,290 72
Grading	2,078 00	369 90	145 00	2,592 90
Supplying braces and stringers to Wilson's Point	1,578 83	284 35		1,863 18
Clearing caving bank of timber	367 00	113 34		480 34
Work during suspension	301 49	44 25		345 74
Total	47,529 27	12,169 32	64,385 90	124,084 49

* Daily cost per ration, raw 25.4, served 32.8 cents; daily cost per ration for actual labor on time list, 39.8 cents.

Work done.

Description.	Length.	Width.	Remarks.
	Feet.	*Feet.*	
Bank graded	5,275	78	
Do	6,146	78	Shoveled.
Bank cleared of timber	8,850	75	Preparatory to grading.
Timber cleared from caving banks	9,240	200	

Work done—Continued.

Description.		Quantity.	Locality.	Remarks.
Snags removed	number	369	Pilcher's Point	
Do	do	172	do	By divers.
Logs removed	do	128	do	
Brush cut and loaded	cords	4,240	Sarah's Island	
Poles cut and loaded	do	151	Pilcher's Point	
Stringers cut and loaded	number	866	do	For Wilson's Point.
Braces cut and loaded	do	729	do	
Track laid	linear feet	15,510	Sarah's Island	
Track corduroyed	do	2,826	do	
Track stored for winter	do	14,030	Ashton	

Carpenter work.—Ventilators put on three quarters-boats; hold of No. 35 fitted for dining-room; addition to office completed.

Painting.—Roofs of three quarters-boats painted.

Respectfully submitted.

J. E. TURTLE,
Assistant Engineer.

CLINTON B. SEARS,
Captain of Engineers, U. S. A.

Statement of material expended at Pilcher's Point, Lake Providence Reach, from November 1, 1883, to October 1, 1884.

Brush	cords	19,325.1
Poles	do	1,710.6
Iron	pounds	86,209
Spikes	do	33,118
Cut nails	do	2,205
Wire	do	80,221
Links	do	2,420
Staples	gross	57
Clevises	pounds	765
Stone	cubic yards	8,666.
Coal	bushels	8,990
Lumber	feet	10,158
Mineral paint	pounds	652
Shingles	number	3,500
Linseed oil	gallons	70
Hercules powder	pounds	175
Primers	number	200
Car grease	pounds	400

Statement of work done at Pilcher's Point, Lake Providence Reach, from November 1, 1883, *to October* 1, 1884.

Description.	Length.	Width.
	Feet.	*Feet.*
Mattress constructed*	1,030	150
Do*	5,372	180
Do*	460	160
Do*	1,245	....
Do*	4,195	165
Do*	1,779	168
Total	14,081	166.5
Grillage	1,768	50
Upper bank revetment	1,395	60
Do	4,330	78
Mattress sunk	1,030	150
Do	5,372	180
Do	460	160
Do	1,245	....
Do	3,074	165
Do	1,779	168
Total	12,960	166.5

* These widths do not include grillage.

H 3.

REPORT OF W. M. CHILDS, ASSISTANT ENGINEER, UPON OPERATIONS AT MAYERSVILLE ISLAND, WITH SUBREPORT UPON EXAMINATION OF SUBAQUEOUS MATTRESSES.

WILSON'S POINT, LA., *October* 1, 1884.

SIR: The work under my charge for the eleven months ending September 30, 1884, was confined to the protection of the face of Mayersville Island by subaqueous mattress and revetment, and to making woven and grillage foot-mats, tilted screens and wattling at the Cottonwood system of dikes.

Careful examinations were made in September, by a marine diver, of the subaqueous mattress along the entire face of Mayersville Island (see subreport marked Appendix H 3[1]).

From the head of the island to a point 300 feet below range 52 the mattress has had a strong current to withstand, and is somewhat broken near the low-water line. The revetment is good, but has been repaired in places several times.

From a point 300 feet below range 52 to a point 180 feet below range 55 the subaqueous mattress and revetment are in good condition. Over 1,500 linear feet of subaqueous mattress and revetment has been built to keep work now standing in repair.

Work done at the cottonwood dikes is in good condition throughout.

Below is an estimate of the labor cost for 100 linear feet of bank protection work:

150 squares woven mattress, at $1.25	$187 50
10 squares grillage mattress, at $2.37	23 70
Grading mattress, at 31 cents	31 00
50 squares revetment, at $2.37	118 50
Total	360 70
Add cost of material:	
150 cords brush, at $1.75	$262 50
147 cubic yards stone, at $2	294 00
12 cords poles, at $2	24 00
130 pounds spikes, at 4 cents	5 20
225 pounds wire, at 7 cents	15 75
1,000 pounds iron rods, at 5 cents	50 00
	651 45
Towage estimated at 33⅓ per cent. of tow-boat service	70 80
Total cost for 100 linear feet	1,082 95
Cost per single foot	10 83

Recapitulations of work done and percentage washed out (**not including Assistant Engineer J. E. Turtle's work**).

	Linear feet.
Woven mattress:	
Mayersville Island (in good condition)	5,735
Cottonwood dikes (in good condition)	4,602
Mayersville Island (washed out)	3,798
Total	14,135

26⅘ per cent. washed out.

Grillage mattress, Mayersville Island, 780 linear feet washed out.

100 per cent. washed out.

Grillage foot-mat, Cottonwood dikes (in good condition)	linear feet..	4,058
Wattling foot-mat, Cottonwood dikes (in good condition)	do....	2,571
Tilted screen, Cottonwood dikes (in good condition)	do....	1,487
Rod braces put up, Cottonwood dikes	number..	709

	Linear feet.
Revetment:	
Mayersville Island (washed out)	6,578
Mayersville Island (in good condition)	5,735
Cottonwood dikes (in good condition)	120
Total	12,433

52¹⁄₂ per cent. washed out.

	Linear feet.
Grading Mayersville Island (in good condition)	8,611
Grading Cottonwood dikes (in good condition)	120
Total	8,731

Of mattress work in good condition, as per last yearly report, 100 per cent. is now washed out.

Tabulated statement of location, amount and cost of work done, and material expended, accompanies this report, marked Appendix H 3[1].

Respectfully submitted.

Your obedient servant,

W. M. CHILDS,
United States Assistant Engineer.

To ARTHUR HIDER,
United States Assistant Engineer in charge.

H 3[1].

REPORT OF W. M. CHILDS, ASSISTANT ENGINEER, UPON EXAMINATION OF SUBAQUEOUS MATTRESSES.

WILSON'S POINT, LA., *October* 4, 1884.

SIR: I have the honor to make the following report of examinations of subaqueous mattress off the face of Mayersville Island, made by a marine diver.

From the head of the island (1,100 feet above range 52) down-stream 500 feet the mattress is in good condition and lies on a gradual slope. Between points 500 and 600 feet below head of island the mattress is badly broken. There are two places in this distance of 100 feet where the mattress is entirely gone out. Below the head of the island 900, 1,000, and 1,100 feet the mattress is broken in places along the low-water line and in two places is broken away from the grillage mat and settled down 3 or 4 feet below the outer edge of the latter. For 75 feet out from the shore the mattress seems in good condition, well ballasted, and lies on a gradual slope.

The revetment from the head of the island down 1,400 feet is very steep near and at the water surface and in some places shows signs of giving way. From a point 1,400 feet below the head of the island to a point 180 feet below range 55, a distance of 6,900 feet, the mattress and revetment are in good condition, and lie on an easy slope. At some places along this stretch the river bed has washed down 3 or 4 feet below the outer edge of the mattress.

The current was so swift the diver could reach the outer edge of the mattress only between ranges 53 and 58.

About 350 feet below range 55, a piece of mattress about 100 feet in length was found and in good condition; 200 feet below this a small patch was found, but from there down nothing of brush or stone was found. The current was quite swift along the lower part of the island and the diver could not go more than 50 feet from shore.

All mattress work found was well ballasted with rock, and was almost covered with sand. Even along the head of the island where is the most current the mattress was well buried in sand. A good deal of light sediment has settled on the mattress between ranges 53 and 55.

Pieces of brush were broken off and brought up, and seem in a good state of preservation. No difference could be detected between brush that had been down one year from that which had been down two years.

Respectfully submitted,

W. M. CHILDS,
United States Assistant Engineer,

To ARTHUR HIDER,
Assistant Engineer in charge.

Description of work done.	Location.	Length.	Width.	Squares.	Rate. Per linear foot.	Rate. Per square.	Cost. Pay-roll and bal steno
Woven mattress	Mayersville Island	2,906	151	4,388			
Do	do	2,829	135	3,819			
Do *	do	310	125	387			
Do †	do	904	110	994			
Do ‡	do	1,774	100	1,774			
Do †	do	407	71	289			
Do †	do	403	45	182			
Do	Cottonwood Dikes	2,975	75	2,231			
Do	do	1,627	60	976			
		14,135		15,040	$1.328	$1.248	$18,773 16
Do §	Mayersville Island	1,395	140	1,953			
Do	do	15,530		16,993			
Grillage mattress †	do	780	50	390	1.186	2.372	925 06
Do §	do	1,395	32	446			
		2,175		836			
Revetment ‖	do	12,313		6,511			
Do	Cottonwood Dikes	120		103			
		12,433		6,614	1.259	2.367	15,654 56
Do §	Mayersville Island	1,395	60	837			
		13,828		7,451			
Grading	do	8,611		70,799			
Do	Cottonwood Dikes	120		250			
		8,731		71,049	.3069	.0377	2,679 74
Grillage foot mattress	do	1,924	60	1,154			
Do	do	2,134	35	747			
		4,058		1,901	.4864	1.038	1,973 69
Wattling	do	2,571		259	.1889	1.875	485 71
Tilted screen	do	1,487	35	520	.2039	.5832	303 26
Rod braces put up	do	(¶) 709			(**) .2123		150 53
Brush cut and loaded	Mayersville Island	(††) 2,045			(‡‡) 3.224		6,593 83
							47,539 54

* Built to repair slides. † Washed out. ‡ 525 linear feet washed out; 1,249 linear feet built to repair slides. § Work done by Assistant Engineer J. E. Turtle. ‖ 5,029 linear feet washed out; 1,549 linear feet built to repair slides. ¶ Number. ** Per rod. †† Cords. ‡‡ Per cord.

Material expended.

Stone	cubic yards	15,791
Brush	cords	16,344
Poles	do	1,155
Spikes	pounds	12,557
Iron rods	do	76,467
Wire	do	52,891

H 4.

REPORT OF C. P. RUPLE, ASSISTANT ENGINEER, UPON OPERATIONS OF DIKE PARTY.

WILSON'S POINT, LA., *October* 1, 1884.

SIR: I have the honor to submit herewith the following report of operations, cost of work, and maintenance of what is here known as the dike party, under my charge, from November 1, 1883, to October 1, 1884.

This party was under active operation at time of last report, made November 1, 1883, and continued so until January 7, 1884, at which time work was entirely suspended on account of high water, and the force disorganized.

At this time but little pile-driving was being done, the principal work consisting in completing the dike already driven, by the construction and sinking of foot-mats, wattling, &c. Fortunately this work was complete to such an extent that what remained unfinished was of little or no consequence.

During the high water, and while the levees on this reach between Wilson's Point, Louisiana, and Concordia Landing, Louisiana, were in danger, I was detailed on patrol duty over this section, also superintending such work as was done to preserve and keep the levees intact, by building revetments of lumber to prevent caving, and when the levee was low or had been cut through, by raising such places with rows of sacks filled with earth placed along the outer edge of the levee.

On the 1st of April, 1884, the force was reorganized and pile-driving resumed by the commencement of the Cottonwood system of dikes, completing this and moving in turn to Baleshed, Stack Island, and Duncansby.

During my absence on leave, from April 23 to June 20, work was continued under the charge of Assistant Engineer E. C. Tollinger.

No dike work has been done since August 15.

The force was then reduced (on account of the unhealthy season) to a few men, and the party engaged in miscellaneous work—at the present time loading rock from the bank onto barges, at Wilson's Point, Louisiana.

On August 28 I took charge of a party to make a special survey of Greenville Harbor, Mississippi, completing this and returning to Wilson's Point September 4, the object of this survey being to secure data upon which to base an estimate of such work as would be necessary to preserve this harbor from further encroachments of the river.

The following is a tabulated statement giving in detail the work done:

Statement showing dike and brush work as done by dike party from November 1, 1883, to October 1, 1884.

Location and dike.	Number of feet driven from November 1, 1883, to October 1, 1884.	Foot-mat between piling.				Woven mat along piling.	
		Made.		Sunk.			
		Lin. feet.	*Sq. feet.*	*Lin. feet.*	*Sq. feet.*	*Sunk.*	*Width.*
Duncansby:							
Main between 6 and 7	1,677	1,677	67,080	477	19,080		
No. 3		150	7,500	150	7,500		
No. 4	1,882	2,032	69,602	1,832	63,602		
No. 6	517	805	32,380	805	32,380		
No. 7	138	782	23,840	1,273	54,420		
No. 8	56	56	2,520	710	38,645		
Cottonwood:							
Main outer	4,471						
Main inner	1,350						
No. 1	863						
No. 2	1,285						
No. 3	558						
Mayersville:							
No 1	100	900	43,870	900	43,870		
Baleshed:							
Main	134	1,570	78,820	1,912	89,489	1,594	60
Main between 1 and 3	2,850						
No. 3				672	29,624		
New 4 under old 4	1,207						
New 5 under old 5	1,206						
No. 5 old	100	354	13,660	829	33,160		
No. 6	366						
No. 7	100			75	3,750		
No. 8	100						
Stack Island:							
Main	2,249	2,369	95,760	2,369	95,760		
No. 1	2,636	2,131	88,895	2,131	88,895		
Totals	23,845	12,964	523,927	14,144	600,175	1,594	60

Statement showing dike and brush work as done, &c.—Continued.

Location and dike.	Shore mat or revetment made and sunk.	Screens hung.		Wattling.		Tip grillage wattling made and sunk.	
	Sq. feet.	*Lin. feet.*	*Sq. feet.*	*Lin. feet.*	*Sq. feet.*	*Lin. feet.*	*Sq. feet.*
Duncansby:							
Main between 6 and 7							
No. 3							
No. 4	1,600	170	3,260			1,280	38,400
No. 6	5,500			1,675	15,731		
No. 7							
No. 8				1,650	10,868		
Cottonwood:							
Main outer							
Main inner							
No. 1							
No. 2							
No. 3							
Mayersville:							
No. 1	9,000						
Baleshed:							
Main				1,865	11,525	2,647	105,416
Main between 1 and 3							
No. 3	3,300	300	9,000	872	6,800		
New 4 under old 4							
New 5 under old 5							
No. 5 old							
No. 6				400	2,400		
No. 7				915	6,405		
No. 8							
Stack Island:							
Main							
No. 1							
Totals	19,400	470	12,260	7,377	53,729	3,927	143,816

Of this there are—

	Linear feet.
Two rows	4,873
Three rows	18,792
Four rows	180
Total	23,845

Amount of pay-roll	$37,454 22
Subsistence	9,227 50
Total	46,681 72
Labor loaned other parties	366 93
Total to be accounted for	46,314 79

Distributed as follows:

1. Pile-driving, including bracing	26,367 42
2. Brush work, foot-mats, &c., including sinking	16,310 87
3. Miscellaneous work:	
(*a*) Cleaning bank of timber	482 86
(*b*) Repairs to revetment, Island 93	1,309 99
(*c*) Ballasting revetment and foot-mats made by other parties not included in above statement	660 62
(*d*) Cutting and loading brush	448 61
(*e*) Loading material	482 19
(*f*) Raising and moving sunken driver	252 23
Total	46,314 79

8,046 piles driven, at $1.725—	13,876 69
5,383 braces put on, at $1.157+	6,231 17
3,193 stringers hung, at $1.96+	6,259 56
Total	26,367 42

Labor, cost per 100 linear feet, 2-row dikes	81 43
Labor, cost per 100 linear feet, 3-row dikes	120 87

For 1882–'83 the cost of the same class of work was $129.40 for a dike of two rows.

Average cost per 100 square feet foot-mat between piling:

Making	$1.313	
Sinking	.586	
		$1.899
Average cost per 100 square feet wattling		2 00
Average cost per 100 square feet tip-grillage wattling		2 10

Average number piles driven per day per driver, while working, 11¾.

Very respectfully,

C. P. RUPLE,
United States Assistant Engineer.

ARTHUR HIDER,
Assistant Engineer in charge.

H 5.

REPORT OF E. C. TOLLINGER, ASSISTANT ENGINEER, UPON LEVEES, VICINITY OF ILLAWARA, LOUISIANA, AND SKIPWITH, MISSISSIPPI.

WILSON'S POINT, LA., *October* 1, 1884.

SIR: During the high-water season I was detailed on special duty on levees in the vicinity of Illawara, La., and Skipwith, Miss., where danger of breaks was imminent, superintending the necessary protection work done by the Government at the former locality, and attending to other duties connected with the levees during the flood.

On April 23 I took charge of the pile-driving force then at work on Cottonwood Bar during Assistant Engineer Ruple's absence on sick-leave. This work was finished and the party moved to Baleshed, when a high-water main dike from 1 to 4 was driven, gaps in 4 and 5 closed, 4 and 5 strengthened from main dike and extended out into deep water, dikes 6, 7, and 8 extended as far as the depths of water would allow.

The party was then moved to Stack Island, and the construction of a dike across Baleshed Chute, above the head of Stack Island, begun. This work was well under way when Assistant Engineer Ruple returned, June 20.

In the mean time, a gap broke through main Baleshed Dike below No. 5, and was continually increasing in size, with a rapid current flowing through. A force of pile-drivers was put to work closing the break in this dike.

All work done by me from April 23 to June 20, while I was temporarily in charge of the party, is included in Assistant Engineer C. P. Ruple's report. On July 1 a separate party was organized, and the following work done:

MAYERSVILLE SYSTEM.

Dike No. 1 repaired. The work done here was to close the break made during the flood, which was done by a dike in front of the gap and a thick foot-mat.

BALESHED SYSTEM.

Main dike from 3 to 5, to protect dike driven in 1882, which showed signs of weakness. Dike immediately below No. 5—to close break, foot-mat made from 3 to 6, incline grillage built from 5, crossing the break, to retard the flow of water passing through the gap. In front of this gap some old condemned coal-barges were sunk. The deep water and strong current passing through the break while this work was being done rendered it exceedingly difficult and costly. Assistant Engineer Stenbing's force was placed in my charge August 1, he having been assigned to other work. The construction of foot-mats was completed at this locality and on August 9 the force transferred to Wilson's Point, and has since been engaged in loading rock from the bank for use at Pilcher's Point. This work has been done during the hot weather with a small force, it being impossible to retain men at wheeling rock when other work could be obtained, and has been done at a very considerable disadvantage.

The statements below show the locality and amount of work done from July 1 to October 1, 1884:

DIKEWORK (PILE-DRIVING).

Location.	Description.	Driven since July 1, 1884.	Remarks.
		Feet.	
Mayersville	Cross-dike 1	649	Closing breaks.
Baleshed	Main dike between 3 and 5	1,508	Protection dike.
Baleshed	Main dike below 5	1,163	600 of this closes break.
Total		3,320	

	Feet.
2-row	590
3-row	2,049
4-row	681
Total	3,320

DIKE WORK (BRUSH).

Locality.	Foot-mat between piling.				Tipped screen.				Revetment.
	Made.		Sunk.		Made.		Sunk.		
	Linear feet.	*Square feet.*	*Linear feet.*	*Square feet.*	*Linear feet.*	*Square feet.*	*Linear feet.*	*Square feet.*	*Square feet.*
Mayersville No. 1, between 3 and 6	597	20,010	597	20,010					6,300
Baleshed main dike	1,975	67,065	1,975	67,065					
Baleshed main dike below 5					882	39,690	882	39,690	
Total	2,572	87,075	2,572	87,075	882	39,690	882	39,690	6,300

The following is a summary of the amount and cost of labor:

Amount of pay-rolls	$6,311 13
Subsistence	1,612 36
Total	7,923 49
1,246 piles driven, at $2.51+	$3,055 05
408 stringers in place, at $1.62+	660 99
1,000 braces in place, at 51 cents+	514 60
870.75 squares foot-mat, at $1.15+	1,001 36
396.9 squares tipped screen, at $1.05	416 74
63 squares revetment, at $1	63 00
3,993 cubic yards stone, loaded, at 42 cents+	1,687 70
Sinking barges, gap in Baleshed	148 05
Miscellaneous, loading piles, and repairs to drivers	276 00
Coaling steamboats	100 00
Total	7,923 49

Respectfully submitted.

E. C. TOLLINGER,
Assistant Engineer.

ARTHUR HIDER,
Assistant Engineer in charge.

H 6.

REPORT OF E. D. THOMPSON, ASSISTANT ENGINEER, UPON SURVEYS LAKE PROVIDENCE REACH.

WILSON'S POINT, LA., *October* 4, 1884.

SIR: The following report, from November 1, 1883, to October 1, 1884, is respectfully submitted:

FIELD WORK.

General surveys.—Three of these, each extending from Ashton to Point Lookout, have been received, viz, two at medium stage, in February and July, and one at flood stage in April, 1884. They included, besides the hydrography, the determination of changes in shore-lines caused by caving banks, and the location of exposed bars and of construction works. Eighty regular ranges were sounded for each survey, the soundings being located by either sextant or transit angles. For the February survey, the shore-line was re-run on both sides of the river the entire length of the reach.

SPECIAL SURVEYS.

These have been made for two purposes: First, to determine the fills and scours due to the contraction works, and, second, to ascertain "whether, in a well-marked bend, where there are caving banks, there is a deposit during falling stages, and, if so, its amount and character, and conversely if a scour takes place during rising stages."

For the first, complete local surveys, including cross-section and longitudinal soundings, were made immediately preceding the construction of any new works, and also for the works standing November 1, 1883, the observations being frequently repeated to ascertain the effects.

For the second, three ranges, each 1,000 meters apart, were selected in Louisiana Bend and sounded frequently during rising and falling stages. These surveys commenced February 4; they were repeated as frequently as possible during the rise of that month and in March. From June to October they were continued, but, owing to the fluctuating stages of the river during that time, now rising and then falling, it is not desirable to base general deduction upon the results of the latter surveys.

A table accompanying this report shows some of the results obtained.

DISCHARGE OBSERVATIONS.

In accordance with instructions received from Capt. W. L. Marshall, a section for the measurement of discharge was located at Wilson's Point in November, 1883.

The observations have been made, in point of time, as follows:

When the river was below mid-stage (18.2 L. P. gauge), once per month; when above mid-stage, once per week.

During the flood stage, in March, they were made daily or on alternate days until the maximum discharge had been determined.

This was 1,151,230 cubic feet per second, with a mean velocity of 6.2002 feet per second (L. P. gauge, 38.11).

All the velocity observations were taken with a W. G. Price current meter, used from a catamaran in the usual manner. No anchorages were used, the apparatus being held in place by a steamboat. Eleven velocity verticals were used for each set of observations, the data taken at each vertical consisting of a run of five consecutive minutes at mid-depth and an integration. The velocity stations are located on the discharge section by ranges on shore making angles of 45° with it.

With a small stern-wheel boat, no trouble was experienced in maintaining any desired position in the river.

When located, the section crossed the head of Cottonwood Bar, but the movement of this bar down-stream has since been quite rapid, the result being to more nearly equalize the depths on the entire section. In connection with the discharge observations, bench-marks were established on both banks for the determination of local slope. The gauge used by the observation party at Hays' Landing, in 1881–'82, was also re-established, in order that comparisons might be made between the observations taken there the previous season and those at Wilson's Point. In all, thirty-four measurements have been made. Maps showing the following curves, viz, velocity, area, discharge, mean depth, and mean velocity, derived from the observations, together with those of the Lake Providence and discharge-section gauges, accompany this report, also a table of results obtained.

SLOPE OBSERVATIONS.

These were taken at twelve stations on the reach from Carolina to Hays' Landing the distances between the stations averaging about 3 miles; four complete sets have been obtained, including a series of high-water marks for 1884. Their elevations referred to zero of L. P. gauge are as follows:

	Feet.
Carolina Landing, Miss	46.493
Ashton Landing, La	45.596
Pilcher's Point Landing, La	43.487
Wilson's Point Landing, La	41.698
Mayersville Landing, Miss	41.303
Lake Providence, La	38.400
△ Shipland, Miss	36.539
Hays' Landing, La	34.900

The elevation of the mark at Hays' Landing for 1884 is 0.117 foot higher than for 1882, and is attributed to backwater from the Yazoo River. The gauge records show that while at Wilson's Point, March 11 and 24, the gauge heights were the same, at Hays' Landing, on March 24, the gauge was 0.95+ foot higher than on the 11th instant.

GAUGES.

At Wilson's Point and Lake Providence, gauges have been maintained throughout the eleven months. New gauges were established as follows: Carolina, June 12, 1884; Pilcher's Point, June 12, 1884; Hays' Landing, February 12, 1884. The Pilcher's Point gauge was discontinued on account of caving banks. The four remaining gauges are read twice daily and reports rendered by the observers every ten days.

MISCELLANEOUS.

A rigid basis for maps has been kept up, including new triangulation where necessary, repairing and re-establishing ranges, and the determination of elevation for new bench-marks where caving has occurred.

The systems of dikes have been resurveyed, construction works located for progress sketches, &c.

A survey of Greenville Harbor was made in September by a portion of the party in charge of Assistant Engineer C. P. Ruple, who has submitted a report on the same.

During August and September, soundings were taken on the shallow crossings of the reach every ten days. The depths reported are the least found in a channel 1,000 feet wide. The crossings sounded were, first, from △ MacMillan (Elton) to foot of Stack Island, and second, from Ben Lomond, Miss., to Shorts, La. On the first, in the channel usually run by steamboats, not less than 15 feet was found at any time, and recent soundings (October 2, 1884) show a least channel-depth of 21 feet (L. P. gauge, 6.00).

The cost of the party for eleven months has been as follows:

Amount of pay-roll	$10,356 65
Subsistence	1,957 36
Total	12,314 01
Average cost per month	1,119 45

Which amount does not include value of coal burned by steamboat.

OFFICE WORK.

One hundred and ten maps and 159 tracings have been made, including progress sketches. In addition, the discharge measurements have been computed, and the special surveys reduced by planimeter, and tables of results prepared and submitted (to June 8, 1884); besides this, a variety of miscellaneous work has been done, including a complete index of all maps and note-books belonging to the party and the Wilson's Point office.

Summary.

General surveys of reach	3
Special surveys	73
Discharge measurements	34

Slope observations	sets..	4
Shore-lines	miles..	119¾
Levels	do...	45
△ built		8
△ located		2
Cross-section soundings (number located)		22,841
Longitudinal soundings		2,502
Maps made		110
Tracings		159

STAGE OF RIVER.

The river was above mid-stage, viz, 18.2 feet, L. P. gauge, two hundred and thirty-nine days, on the following dates, viz, November 18, 25, 28, December 20, 1883, and December 31, 1883, to July 28, 1884.

	Feet.
Highest reading, L. P. gauge, March 23, 1884	38.40
Lowest reading, L. P. gauge, September 30, 1884	5.85
Oscillation of river	32.55
Mean stage of river from November 1, 1883, to October 1, 1884	24.07

CAVING BANKS.

Louisiana Bend.—The length of caving bank in this bend extended during the flood stage from Range 18 to Range 26, 17,920 feet. The maximum amount of caving occurred on Range 24, viz, 1,000 feet; average annual rate was 575 feet.

This bank has since been mattressed nearly to Range 22. The channel followed the caving bank closely, Sarah's Island bar enlarging accordingly. The deepest sounding taken in the bend during flood-stage was 151 feet on Range 18.

The current was then very swift with large whirls and eddies near the Louisiana shore. The decrease in datum area on Range 18 from February 4, 1884 (L. P. gauge, 24.8), to February 22, 1884 (L. P. gauge, 37.45 feet), was 1,880 square feet.

No caving occurred on this section. On Range 22, where heavy caving took place during the same time, the increase of datum area was 11,688 square feet.

Ranges 31 to 34, Mississippi (Island No. 92).—The caving in this locality is not at all serious, excepting perhaps at △ Cordell, where it extends back 300 feet. No recent survey has been made to determine its rate. Length of caving bank, 5,670 feet.

Ranges 38 to 41½, Louisiana.—Length of caving bank, 5,660 feet; annual rate of caving, 150 feet.

Below mouth of Duncansby Chute, Mississippi.—The caving along this bank began in November, and has continued more or less ever since. Length of caving bank, 8,350 feet; annual rate, 175 feet.

Longwood Front.—Length of caving bank, 11,000 feet; annual rate, 125 feet.

Ranges 82 to 88 (Montgomery's, La.).—During the rising stage in January and February, 1884, rapid caving took place in this locality, destroying the old levee. Length of caving bank, 10,420 feet; annual rate, 275 feet.

Shipland Front, Ranges 94 to 100.—Slight caving occurred here during the flood-stage. Length of caving bank, 6,600 feet; annual rate of caving, 125 feet.

CHANGES ON REACH.

Duncansby Chute.—Upper Duncansby Tow-head was entirely washed away in February and March, 1884; at the same time a fill took place in the chute below, amounting to 1,035 feet on a section between Dikes 6 and 7.

For comparison, six sections were selected, Range 35 above the dikes, Ranges 36 S, 37 S, above and below Dike No. 6, and Ranges 40, 41, and 42 in the chute above Skipwith Landing.

The following statement shows the average amounts of fills that have taken place on the sections between the specified dates:

Average, December 3, 1883, to June 5, 1884:	Feet.
Range 36 S	4.48
Range 37 S	10.35
Average, November 14, 1883, to June 5, 1884:	
Range 40	2.58
Range 41	3.57
Range 42	2.89

The low-water channel is now where the upper tow-head formerly was.

COTTONWOOD BAR.

The construction of contraction works on this bar during the high stage has had the effect of building up a large bar behind them, and of throwing the channel directly into the bend of Island No. 93.

MAYERSVILLE CHUTE.

Four sections have been sounded for comparison in this chute, viz, one about 500 feet above the cross-dike and three below, from 500 to 850 feet apart.

The dike consists of five rows of piling, with a heavy drift accumulation in front.

From November 14, 1883, to June 4, 1884:

	Feet.
Range 52 shows a scour of	3.16
Range A shows a scour of	5.53
Range B shows a scour of	1.76
Range 53 shows a fill of	1.18

Range A is located below the dike, and the large amount of scour is due to a break, which occurred April 21, next Mayersville Island.

BALESHED CHUTE.

In this chute four ranges were selected for comparison.

From December 5, 1883, to June 6, 1884:

	Feet.
Range 60 S shows a fill of	4.53
Range 61 S shows a fill of	4.38
From November 16, 1883, to June 6, 1884:	
Range 64 A shows a scour of	2.3
Range 65 A shows a fill of	22

At the upper end of the chute the cross-dikes extend from the main dike to the Mississippi shore; while at the lower end the depth of the water is such that the dikes cannot be driven across. The Baleshed Bar has increased both in width and length, its lower extremity being now within 200 meters of the head of Stack Island, with a width of 680 meters on Range 72 (L. P. gauge, 6.05 feet).

STACK ISLAND CHUTE.

Three sections have been selected for comparison ranges, 71 and 72 both extending across the river, and Range 73 in the chute proper.

From February 5 to April 23, 1884, during the rising and high stages, a slight scour of .84 foot took place in the chute; on Range 72, inside the dike, the fill averaged 2.62 feet; on Range 73, an average scour of 10.5 feet took place.

On September 24, 1884, the deepest water found on Range 72 (below the cross-dike) was 0.8 foot, and on Range 73, 47 feet (L. P. gauge, 6 feet).

A tabular statement showing results of comparative surveys is submitted herewith.

MAYERSVILLE ISLAND.

During high water about 1,800 feet of the lower end of the island, consisting of a very narrow strip between the chute and the main river, was washed away.

MISCELLANEOUS.

No low-water survey has yet been made; hence a direct comparison of the reach for the low-water stages of 1883 and 1884 cannot be made at this time.

The progress maps accompanying annual report show all dike and mat work constructed since the beginning of improvements and standing October 1, 1884. Also 6-foot contour lines (L. P. gauge) as they were in December, 1881, before construction work commenced, and in July, 1884.

The maps of comparative sections at Pilcher's Point, Ranges 14, 16, 18, 20, 22, and

24 are taken from surveys of April 5, 1883, September 12, 1883, April 17, 1884, and July 8, 1884. Construction work was begun in this bend about September 1, 1883, and is now in progress.

The sections showing changes in chutes are from surveys of December, 1881, and April and July, 1884, before and after dike construction.

A map of the July general survey on scale of 1 : 50000 is also submitted herewith.

The steam-launch Nellie was used by the party until she was sunk December 31, 1883, by striking a submerged snag. From January to June, 1884, the tow-boats on the reach were used at various times for soundings and gauging operations. In June, 1884, the steamboat Meter, designed and built for the use of the party, arrived, and has been used constantly ever since, giving entire satisfaction.

In January, 1884, a case of small-pox appeared on the quarter-boat, rendering it necessary to organize a new party, delaying the work nearly three weeks.

To my assistants, Messrs. Ritchie, McNulty, Vansickle, Reed, and Lowegren, I am indebted for valuable and efficient services rendered.

Very respectfully,

E. D. THOMPSON,
United States Assistant Engineer.

ARTHUR HIDER,
United States Assistant Engineer in charge.

H 7.

Summary of discharge observations taken at Wilson's Point, Louisiana, from November 1, 1883, to October 1, 1884.

Date.	L. P. gauge.	Area.	Mean velocity per second.	Discharge per second.
1883.		*Square feet.*	*Feet.*	*Cubic feet.*
November 27–28	18.40	118,480	4.418	501,365
December 10	24.35	131,977	5.192	685,244
1884.				
January 30–31	25.30	128,143	5.214	668,304
February 15	34.75	161,923	5.487	888,481
February 26	37.48	173,589	5.952	1,033,216
February 27	37.60	170,760	6.085	1,039,292
February 28	37.66	172,887	5.987	1,035,117
February 29	37.72	178,380	5.954	1,062,144
March 3	37.72	174,284	5.939	1,035,130
March 6	37.87	183,870	5.914	1,087,561
March 11	38.11	185,676	6.200	1,151,230
March 13	38.12	182,880	6.131	1,121,330
March 17	37.86	183,332	5.969	1,098,032
March 19	37.97	183,308	5.846	1,071,788
March 21	38.29	185,504	5.522	1,024,450
March 24	38.39	188,420	5.589	1,053,212
March 26	38.25	186,263	5.611	1,045,166
March 28	38.05	186,464	5.477	1,021,260
April 5	37.06	188,202	5.517	1,038,454
April 12	36.68	189,008	5.525	1,047,741
April 16	36.69	186,570	5.704	1,064,339
April 24	36.72	188,164	5.605	1,054,786
May 3	36.51	192,082	5.504	1,0[illegible]8,829
May 10	36.53	180,430	5.603	1,011,027
May 16	36.33	185,106	5.541	1,025,762
May 27	34.35	178,040	5.140	915,129
June 11	24.50	148,000	4.156	615,139
June 17	24.98	146,201	4.385	641,124
June 23	25.50	150,930	4.299	648,928
June 28	24.39	145,800	4.276	623,964
July 7	21.60	132,720	4.264	566,011
July 22	18.90	132,960	4.109	546,[illegible]
August 14	14.95	114,830	3.439	394,946
September 17	7.15	90,710	2.973	269,[illegible]

COMPARATIVE SECTIONS.

LOUISIANA BEND—RANGE 18.

Date.	W. S.	L. P. gauge.	Areas below datum.	Scour.	Fill.
1884.			*Square feet.*		
February 4	31.15	24.81	249,560	....	....
February 11	37.11	31.55	229,144	....	20,416
February 13	38.92	33.57	239,880	....	9,680
February 16	40.50	35.35	228,106.4	....	21,453.6
February 18	41.30	36.30	250,966.4	1,406.4	....
February 22	42.65	37.45	247,680	....	1,880
February 26	43.55	37.49	249,080	....	480
February 29	43.70	37.72	223,531.2	....	26,028.8
March 28	43.45	38.06	226,800	....	22,760
April 17	42.90	36.65	225,976	....	23,584

LOUISIANA BEND—RANGE 22.

Date.	W. S.	L. P. gauge.	Areas below datum.	Scour.	Fill.
February 4	30.95	24.68	281,632	....	....
February 10	35.94	30.80	281,280	....	352
February 13	38.55	33.54	286,160	4,528	....
February 16	40.20	35.35	297,200	15,568	....
February 18	41.00	36.30	299,440	17,808	....
February 22	42.35	37.43	293,320	11,688	....
February 26	43.25	37.48	272,208	....	9,424
February 29	43.40	37.72	259,760	....	21,872
March 28	43.15	38.05	269,328	....	12,304
April 17	42.70	36.65	244,087	....	37,545

DUNCANSBY CHUTE—RANGE 37 S.

Date.	Water surface, Wilson's Point gauge.	Below Dike No. 6.			Width of section.	Average depth of fill below datum.
		Areas below datum.	Scour.	Fill.		
1883.		*Square feet*	*Square feet.*	*Square feet.*	*Feet.*	*Feet.*
December 3	24.25	44,160	....	....	1,680	....
1884.						
February 4	25.05	41,945	....	2,215	....	1.32—
March 13	37.72	34,373	....	9,787	....	5.82+
April 8	36.59	33,867	....	10,293	....	6.13—
April 17	36.52	31,440	....	12,720	....	7.57+
June 5	27.30	26,773	....	17,387	....	10.35—

DUNCANSBY CHUTE.—RANGE 41.

Date.	Water surface, Wilson's Point gauge.	1,000 meters below Dike No. 8.			Width of section.	Average depth of fill below datum.
		Areas below datum.	Scour.	Fill.		
1883.		*Square feet.*	*Square feet.*	*Square feet.*	*Feet.*	*Feet.*
November 14	18.15	54,920	....	....	2,650	....
November 23	20.15	55,792	872	....	....	....
December 4	24.85	53,800	....	1,120	....	0.42
1884.						
February 4	25.05	54,920	....	000	....	....
March 13	37.72	53,680	....	1,240	....	0.47—
April 8	36.59	51,232	....	3,688	....	1.39+
April 18	36.52	47,960	....	6,960	....	2.63—
June 5	27.30	45,440	....	9,480	....	3.57

NOTE.—The first survey on each section is taken as the unit of comparison.

MAYERSVILLE CHUTE—RANGE 52.

Date.	Water surface, Lake Providence gauge.	Areas below datum.	Scour.	Fill.	Width of section.	Average depth of fill below datum.
1883.		*Square feet.*	*Sq. ft.*	*Sq. ft.*	*Feet.*	
November 14	16.83	26,373			960	
November 27	18.03	30,667	4,294			
1884.						
February 5	24.50	29,840	3,467			
March 10	38.10	28,107	1,734			
April 21	36.80	28,480	2,107			
May 10	36.52	27,227	854			
June 4	28.30	29,413	3,040			

MAYERSVILLE CHUTE—RANGE A.

Date.	Water surface, Lake Providence gauge.	Areas below datum.	Scour.	Fill.	Width of section.	Average depth of fill below datum.
1883.						
November 14	16.83	25,360			870	
November 27	18.03	24,134		1,226		1.41
1884.						
February 5	24.50	26,960	1,600			
March 10	38.10	26,180	820			
April 21	36.80	26,826	1,466			
May 10	36.52	28,747	3,387			
June 4	28.30	30,160	4,800			

MAYERSVILLE CHUTE—RANGE B.

Date.	Water surface, Lake Providence gauge.	Areas below datum.	Scour.	Fill.	Width of section.	Average depth of fill below datum.
1883.						
November 14	16.83	25,493			895	
November 27	18.03	26,934	1,441			
1884.						
February 5	24.50	28,374	2,881			
March 10	38.10	27,120	1,627			
April 21	36.80	26,320	827			
May 10	36.52	27,200	1,707			
June 4	28.30	27,067	1,574			

MAYERSVILLE CHUTE—RANGE 53.

Date.	Water surface, Lake Providence gauge.	Areas below datum.	Scour.	Fill.	Width of section.	Average depth of fill below datum.
1883.						
November 14	16.83	27,920			996	
November 27	18.03	28,254	334			
1884.						
February 5	24.50	29,360	1,440			
March 10	38.10	28,533	613			
April 21	36.80	28,533	613			
June 4	28.30	26,747		1,173		1.18

NOTE.—Comparisons are made with the first survey on each section.

BALESHED CHUTE—RANGE 60 S.

Date.	Water surface, Lake Providence gauge.	Inside of dike.			Width of section inside dike.	Average depth of fill, inside of dike below datum.
		Areas below datum.	Scour.	Fill.		
1883.		*Square feet.*	*Sq. ft.*	*Sq. ft.*	*Feet.*	*Feet.*
December 5	24.15	28,027			1,400	
1884.						
February 5	24.50	28,040	13			
March 14	38.03	24,913		3,114		2.22+
April 24	36.72	22,546		5,481		3.91+
June 6	26.55	21,680		6,347		4.53+

BALESHED CHUTE—RANGE 61 S.

Date.	Water surface, Lake Providence gauge.	Inside of dike.			Width of section inside dike.	Average depth of fill, inside dike below datum.
		Areas below datum.	Scour.	Fill.		
		Square feet.	*Sq. feet.*	*Sq. feet.*		*Feet.*
1883.						
December 5	24.15	43,680	...	...	1,466	...
1884.						
February 5	24.50	44,186	506	...	...	...
March 14	38.03	39,233	...	4,447	...	3.03+
April 24	36.72	40,480	...	3,200	...	2.18+
June 6	26.55	37,253	...	6,427	...	4.38+

BALESHED CHUTE—RANGE 64 A.

1883.						
November 16	17.25	41,226	...	...	1,688	...
December 5	24.15	43,040	1,814	...	...	...
1884.						
February 5	24.50	43,973	2,747	...	...	...
March 14	38.03	47,680	6,454	...	...	...
April 24	36.72	54,260	3,034	...	...	...
June 6	26.55	45,120	3,894	...	...	...

NOTE.—Comparisons are made with the first survey on each section.

STACK ISLAND CHUTE—RANGE 71.

Date.	Water surface, Lake Providence gauge.	Area below datum, inside of dike.	Scour.	Fill.	Width of sections.	Average depth of scour below datum.	Average depth of fill below datum.
1884.		*Square feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*
February 5	24.50	92,160	...	...	2,632	...	...
February 18	36.30	88,480	...	3,680	...	...	1.39
March 14	37.03	92,936	776	...	...	0.29+	...
April 23	36.80	94,376	2,216	...	...	0.84+	...

STACK ISLAND CHUTE—RANGE 72.

1884.							
February 5	24.50	101,120	...	...	2,414	...	...
February 18	36.30	90,904	...	10,216	...	...	4.23+
March 14	37.03	101,860	740	...	...	3.06+	...
April 23	36.80	94,816	...	6,304	...	...	2.61+

RANGE 73 CHUTE.

1884.							
February 5	24.50	81,600	...	...	1,721	...	...
February 18	36.30	85,173	3,573	...	...	2.08—	...
March 14	37.03	92,640	11,040	...	...	6.41+	...
April 23	36.80	99,840	18,240	...	...	10.59+	...

NOTE.—Comparisons are made with the first survey on each section.

H 8.

REPORT OF HENRY STEUBING, ASSISTANT ENGINEER, UPON COST OF UNLOADING AND DISTRIBUTING STONE ON LAKE PROVIDENCE REACH.

WILSON'S POINT, *October* 1, 1884.

SIR: The following is the amount and cost of unloading stone from barges at Wilson's Point, covering revetment of Mayersville Island with stone, and foot-mat work on Stack Island and Baleshed dikes, done by the party under my charge:

4,813 cubic yards stone unloaded from barges, at 25 cents	$1,203 75
5,480 cubic yards stone distributed on revetment, Island 93, at 50 cents	2,792 00
252.5 squares revetment built, repair to revetment, Island 93, at 57 cents	143 92
414 squares foot-mat constructed, Stack Island, Baleshed dikes, at $2	828 00
330 cubic yards of grading, at 30 cents	99 00
101 squares shore revetment, Stack Island dikes	46 18
	5,112 85
Amount of pay-roll	3,858 45
Amount of subsistence	1,254 40
	5,112 85

The party was turned over to Assistant Engineer Tollinger August 1, having been assigned to duty at Pilcher's Point.

Respectfully submitted.

HENRY STEUBING,
Assistant Engineer.

ARTHUR HIDER,
United States Assistant Engineer in charge.

H 9.

REPORT OF H. ST. L. COPPÉE, ASSISTANT ENGINEER, UPON WORK AT DELTA POINT, LA., AND VICKSBURG HARBOR.

VICKSBURG, MISS., *October* 10, 1884.

CAPTAIN: I have the honor, in accordance with instructions mailed me on the 20th ultimo, to submit the following annual report of work under my charge. You instruct me to report on the work up to the 1st of October, but as it will only take to the 10th to finish all the construction that will be needed at this point for some time, I have included these 10 days.

At the time of the last annual report a survey had been made, and the results recorded therein.

Delta Point was in most part intact and but little repairs necessary. The inner harbor had filled to such an extent that, in spite of the money expended in dredging, Captain Marshall would recommend no continuation of the work there, nor submit any further estimate for improvement.

At that time Delta Point was unsettled, as shown in sketch, the only weak part being at the projecting mud point, where mattress dike was built 2,000 feet below Delta Wharf-boat Landing. It was estimated that 500 linear feet of mattress would repair this.

January 1, with an outfit from Wilson's Point, I commenced the construction of a mattress here to be of the length estimated, but the weather was so severe, and the water at such a high stage, that no attempt was made otherwise than to temporarily prevent the caving until a more favorable time; this was accomplished with some difficulty (by sinking a mat 183 by 163 feet, as shown in sketch).

January 16, all the plant taken from the Lake Providence Reach was returned and no more work done on the harbor until the present low-water season.

In the latter part of June you directed me to make a survey of the harbor and Mississippi River in the vicinity, with a view to comparing the results with those obtained in former years, and also for the purpose of ascertaining the condition of the work already done, and the repairs and new work necessary in order to carry out the general plan of improvement.

July 10, after making the survey I sent to your office at Memphis a report on the same, accompanied by maps and estimate. The following extract from it will show the condition of the river and changes then made:

"The changes that have occurred since the last survey, made October of last year, in the main river, as can be seen by studying the map, are as follows:

"The sand-bar above Delta Point has caved, becoming what is termed a bluff-bar, the low-water line being forced towards the Louisiana side 200 feet. The tail of the bar has been moving down-stream each year, showing it to be some hundred feet below the position occupied the year previous. Now the change at the lower end is almost imperceptible. The change at King's Point is also but slight. From immediately at the point just above the line of the old river bank (see map) for 2,000 feet the caving has been about 50 feet, but above and below the interval there has been no change. The soundings in the vicinity of Delta Point, where the bank was revetted, show a slight diminution in depth, due, I think, more to high-water influences than any other cause; a few weeks of low water will deepen the water here again. The bar below King's Point, through which West Pass was cut, and which closes the entrance to the Centennial Lake, has been partially swept away, the low-water line being to some extent forced back towards the old channel of the river (northeast). All the sand which originally formed this middle ground or outer bar has not been effectually caved away, but seems to have moved in part just below its former position, shoaling up slightly the river in the vicinity of the P. line elevator; making an average difference at the lower landing of 8 feet since last year. Just below the last or lowest mattress placed at Delta Point (on the sand-bar) the bank has caved to the extent of 100 feet at a point 600 feet below old work, and 150 feet 1,200 feet below old work. Delta Point proper, where mattresses were placed in 1882 and 1883, is unchanged, with the exception of one or two points where there has been considerable deposit. About 1,200 feet below the P. line elevator on the Mississippi side, the bank commences to cave, increasing as you go down-stream, being very destructive at the Refuge Oil Mill, 1 mile below. At this point it has caved, since August 1882, 800 feet, being now within 66 feet of the track of the L., N. O. and T. R. R., and threatening the site of the mill.

"The soundings in the inner harbor show the changes to be but slight, and different from what had taken place in former years, there being a scour from Glass Bayou to Ryan's upper mill of about 1 foot—in the north end of the lake, the difference, if any, being less. Below the upper mill there is a fill in the line of the old proposed canal bed of channel, varying from 0 to 2 feet.

"On a line called section 1 in the channel near the river side there has been practically no change; on the same line, opposite Point of Willows, the fill has been as great as 4 feet, and half way to West Pass 6 feet. At West Pass the difference is but 1 foot; here the deposit is soft mud.

"To recapitulate, the tendency seems to have been for the river to approach nearer its old bed, cutting away the sand-bar above Delta Point, which commenced to form just after the cut-off in 1876 (and had up to this year been gradually creeping down-stream), turning the thread of the current once more towards the west entrance to the Lake Centennial and sweeping away the middle bar, which last year projected out in the river some distance, as shown on the map."

As stated in that report, I am of the opinion that this more favorable condition of things was entirely, or in great part at least, due to the fact that Delta Point remained immovable; after two years of constant endeavor to wash it away, the river had been forced back towards the old channel.

In the same report I submitted estimates for improvement for the present season, as follows:

Excavating canal basin and West Pass to zero of gauge:	
Basin: Natural slope on city side and slope 8 to 1 on other side	$26,708 10
Canal: Slopes same as basin	13,890 15
West Pass: Slopes 3 to 1	16,958 55
Total	56,556 80
Revetting Delta Point	25,000 00

August 1 there was on hand of funds belonging to this appropriation $1,723.32, and an allotment which had just been allowed by the Commission for improvement of Delta Point, $25,000, making a total of $26,723.32 with which to patch up the breaks (which were developing on the receding of the water) and further revet the Point at the lower end.

August 2 an outfit arrived here from Wilson's Point, with which work was commenced, which consisted, as in former years, in grading the bank, sinking mattresses, and building revetments for upper bank protection. This work has been carried on up to date, with the result shown on the accompanying map.

At first it was proposed to use $22,500 of the $25,000 allotted, in revetting 1,500

feet of the bank below the old work, and the balance of the $25,000 in patching at the upper end of the Point; but on the receding water, as before stated, so many new breaks were uncovered that it was found necessary to take much more of the appropriation for patching than was at first deemed expedient.

The work was commenced by building a mattress at the upper end of the revetment laid in 1882, where the water is extremely swift and the bank was being undermined by the action of the current. Here, in all, about 700 linear feet of mattress was sunk, and the bank graded, and about 460 linear feet of bank revetted; at the lower end of the point (see map) 800 linear feet of mattress was sunk, and 1,040 linear feet of bank graded and revetted; in all, about 1,500 feet of bank protected with willow and stone. The upper work is about 200 feet wide from top of bank to outside edge of mat, the lower being nearly 300 feet. At first the grading was done by hand, but this was found to be so expensive that you sent me a hydraulic grader, which proved, as in 1882, an enormous saving of expense. In addition to this work, I requested permission, while the grader was here, to make an attempt with her to open West Pass, in order that I might get stone from the quarries at Vicksburg for use on the work, also for the benefit of small boats that might enter the inner harbor.

On your granting the request, I placed the grader at the river end of the pass, and with great difficulty worked her through to the lake, making 8 feet of water as she moved, which shoaled up at once to less than 2. In the same way I forced her back to deep water in the river. It took ten days to do the work, and cost $400 for labor, subsistence, and coal, and a day after leaving the pass it was in a worse condition than before commencing the work. The material through pretty much its entire length is compact sand, which shifts continually, at one time being 10 inches below the water surface, and the next day in the same spot 50 inches.

At about the time of finishing the grading at Delta Point it was found to be necessary to move the Vicksburg wharf-boat below its former site to deeper water and where the bank was almost perpendicular. I was requested to grade this bank for the city, the latter paying the expense of running the grader, which I did, after receiving permission from you.

I have had no time or means for making a general survey of the harbor, but have made a detailed reconnaissance; have had a meander line run from the foot of Delta Point to opposite the sand-bar at the mouth of Yazoo, locating the latter, and sections sounded along the Louisiana side where mattresses have been sunk. My reconnaissance serves to show that the conditions are but little changed since the last survey.

The West Pass at the present time (there being a considerable rise in the river) is quite deep, over six feet throughout its entire length, and 75 feet wide, the water passing through it with great velocity into the lake. The basin dredged in front of the city in 1883 is in about the same condition as shown in last report. The canal is about the same also, except where citizens have dammed it up to keep water in the lake. The Headlight, a light draught boat, came into the harbor yesterday and is now lying at the foot of Clay street.

There is no caving at the present stage of water from the mouth of the Yazoo to below the Refuge Oil Mill on the Mississippi side, and none on the Louisiana side from Young's Point to three miles below Delta (town).

The channel of the river is a little deeper or rather at a greater depth below low water than when the river was at a higher stage. It will be seen by the map that Young's Point is being caved away and the bar above Delta Point forced back towards the old shore-line. Unless some unforeseen changes take place at the mouth of the Yazoo (where a small cut-off is being made), I think the river will undoubtedly accommodate itself to the old bank in the Louisiana side, and consequently cut away the bar closing the entrance to the inner harbor.

My reason for making a reconnaissance to the mouth of the Yazoo was for the purpose of ascertaining whether a dike built (on the bar forming there) to deflect the current onto Young's Point would not be advantageous in helping the river to sweep away the bar just below on the Louisiana side, but I found that the work would be more extensive than at first anticipated and the expenditure greater than the results would warrant.

After the subsiding of the next high water I expect to find this in a great part accomplished without the help of a dike. The next high water will probably destroy some of the old revetment at the mattress dike, and the sipe water on the falling river the work in the eddy just below, but even should this occur I look for no further trouble, but believe the work on the Point has accomplished its purpose. There may be some sinking and breaking of the bank, but no more caving.

I will be more competent to anticipate the changes that will take place after plotting the soundings and levels taken on sections along the revetted bank.

At the time these sections were sounded a diver (with submarine suit) examined the bottom, the latter being placed on the section lines by the engineer. The results of his work I will submit with the profiles of the sections as soon as plotted. A general resumé of this work is as follows:

He commenced at the upper end of the revetment placed in 1882, but from there to near the old mattress dike was able to do but little, the current being so swift and dangerous; from there to where the bank is straight and covered with deposit, *i. e.*, in the eddy, he found the mattresses all holding, but badly broken or bent over projecting ridges and into holes in the uneven bottom; in some places they were standing perpendicular and entangled in old screens sunk in 1881. This is the portion of the work which I reported some time ago as being in a condition almost unexplainable. There has been apparently no caving whatever, but the bank has sunk with its covering of stone and willow, leaving steps, or cracks, in the slope at its top, and midway an almost perpendicular side from which the rock has slid, but it did not disturb the upright position of the pile driven through the head of the mat at a ten-foot stage in 1882.

I consider it all, or in a great part, due to the influence of sipe water, which runs from the bank as the water in the river falls, as I wrote. In answer to my communication at that time, you suggested the use of wooden drains or tiles; these would be effective were it not that the water has no single outlet, but comes from the bank in places on a shelf perhaps 100 feet long and in such a manner as to make it impossible to collect it in order to carry it off. I would have attempted some experiments, but there was no occasion for draining in the new work and it would have been too expensive in the old, it being necessary to take away considerable revetment in order to get at the seepage ledges. The patching which it has been necessary to do this season shows to me very conclusively the practicability of grading the bank to a very long or gentle slope before revetting. Had this been done here in 1882 we would have had much less trouble repairing; probably it would have prevented the necessity of repairs.

The work this year has been carried on with great difficulty and at a greater expense than otherwise because of the excessive heat and my inability to get labor. White laborers will not come to this country so early as August and September, those who do come being unable to stand the heat of the sun. At one time thirty men in a force of 150, all but one foreman and the steward, were sick. Our only alternative is negro labor, which is very unreliable. It will be impossible for me to make any estimate of the cost of the work of the past season, either as a whole or in detail, until my accounts are all in and the work closed, which will not be for a few days.

I submit herewith a sketch of harbor and Mississippi River in the vicinity showing changes, and sketch of bank at Delta Point showing condition of work to date.

I am, very respectfully, yours,

H. ST. L. COPPÉE,
Assistant Engineer.

Capt. C. B. SEARS,
Captain Engineers, U. S. A., Memphis, Tenn.

APPENDIX I.

REPORT OF MAJOR AMOS STICKNEY, CORPS OF ENGINEERS, UPON OPERATIONS IN THE FOURTH DISTRICT.

UNITED STATES ENGINEER OFFICE,
New Orleans, La., October 10, 1884.

SIR: I have the honor to submit the following report for works under my charge executed from funds controlled by the Mississippi River Commission during the time from October 31, 1883, the date of the last annual report, to October 1, 1884. The works under my charge included in the fourth district, Mississippi River, are as follows, viz:

Construction and repair of levees.

Improvement of harbors of Natchez and Vidalia.

Improvement of mouth of Red River and rectification of the mouth of Red River and the Atchafalaya River.

Improvement of harbor of New Orleans, La.

LEVEES.

The levees under construction at the date of last annual report were Shipp's Bayou to Hard Times, Hardscrabble, and Bondurant, Kempe and Green's to Fairview.

Owing to bad management on the part of the contractors, the contracts on the first three of these levees were annulled after every effort had been made to compel the contractors to finish their work. A new contract was made for the Shipp's Bayou

to Hard Times Levee, and the other two were undertaken by hired labor. The disorganization of the work and the excessively rainy season made it impossible to complete the levees in time for the flood. The protection levees at Shipp's Bayou to Hard Times and Kempe were, however, held almost to the top of the flood, the former being finally breached from the rear, after the levees above had broken, and the latter giving way during a violent storm, when the river was at its highest. Along the front of Tensas Parish the flood of 1884 exceeded the height of the great flood of 1882 about 6 inches, and in many places went entirely over the tops of the levees. The result was a great number of breaks in both United States and State levees.

Below Red River no United States levees were breached, but some disastrous breaks occurred in State levees. As the flood developed in magnitude allotments were made by the Commission for protecting the levee lines. A great deal of work was done, and a great many threatened breaks prevented. For details concerning levee work I refer you to the report of my assistant, Mr. H. S. Douglas, who, with all others connected with the work, rendered efficient service in a desperate struggle to maintain the lines. From the last appropriation of Congress, made in act approved July 5, 1884, the amount of $160,000 was allotted by the Commission, to be distributed by the Board of Engineer Officers on construction or repairs of levees. The portion of this assigned to the fourth district was $90,000, to be expended on the United States levees on Tensas Front. It is hoped with this amount to repair the United States levees so they will stand even a great flood, but the amount is not sufficient to put them in a condition of perfect safety with regard to height and stable slopes. The estimate of the cost for completing the line of levees in the fourth district will depend largely upon the dimensions of these embankments. The policy of the Commission heretofore has been to build the greatest length of lines with the money available, without attempting to increase the heights above those parts of the line that were standing. The dimensions of the levees as they now exist are undoubtedly entirely too small for security in times of great floods. The gaps in the levees in the fourth district which will remain open after the construction of the levees now provided for are as follows:

Name of gap.	Length in feet.	Estimated cubic yards.	Estimated price per cubic yard.	Estimated cost.
TENSAS FRONT.				
Diamond Bend to New Carthage	50,000	410,000	$0 30	$123,000 00
Bougere Crevasse	23,400	637,000	30	191,100 00
Black Hawk to Red River	90,000	500,000	30	150,000 00
ATCHAFALAYA FRONT.				
Morganza	6,000	300,000	30	90,000 00
Total	169,400	1,847,000	....	554,100 00

NOTE.—The height of these levees, as estimated, equals grade of adjacent existing levees.

The following is the report of Mr. H. S. Douglas, who has special supervision of levee work:

"CONSTRUCTION AND REPAIR OF LEVEES AND SURVEY OF UNLEVEED FRONTS.

"UNITED STATES ENGINEER OFFICE,
"*New Orleans, La.*, *October* 1, 1884.

"SIR: I have the honor to submit the following report on 'construction and repair of levees,' and the 'survey of unleveed fronts,' from October 31, 1883, to October 1, 1884:

"During the period a most extraordinary and disastrous flood has occurred in the Mississippi River. The levees, both State and United States, have been severely tried, and in many cases were found inadequate to restrain the flood. Numerous breaks occurred, and others were only prevented by extraordinary efforts. During the flood, authority having been given, work was undertaken for the preservation of both State and United States levees. Large quantities of material were furnished and work done for this purpose, principally upon State levees, which were frequently found lacking in cross-section, crown, and height. It is gratifying to note that breaks occurred in but two completed United States levees.

"On October 31, 1883, six of the eleven levees on which contracts had been let had been completed and received, and of the remaining five two have been completed and

received to date. The non-completion of the three remaining levees is attributable to the failure of contractors to place adequate forces upon their works, to the early rise of the river, and to a very unfavorable working season.

"The following gives progress on each levee in detail, and its present condition:

"TENSAS FRONT.

"Castleman's to Buck Ridge, near Point Pleasant. This levee was completed under contract prior to October 31, 1883. On March 15, 1884, the river had risen to 45.95 on the Vicksburg gauge, 2.8 feet below the high water of 1882, and at that time the levee was reported by residents of the locality to be safe, they anticipating danger only from the waters going over the tops of the old levees at certain low points. The river continued steadily to rise, however, and on the night of March 20 the first break occurred.

"Between the 20th and 23d fifteen breaks occurred in the State and United States levees at this point, eleven being in the new Government work. The flood went over the tops of nearly all the levees in this locality, and the new work, not being as well grassed and settled as the old, suffered the most.

"The breaks have all been surveyed and staked out since the decline of the flood. It is estimated that 22,000 cubic yards of earth will be required to close the breaks; and under the recent allotment for construction and repair of levees this work was advertised and bids for it opened September 27, 1884.

"SHIPP'S BAYOU TO HARD TIMES.

"Work was in progress on this levee October 31, 1883, under contract. Slow progress was made, and though the contractor was repeatedly directed to increase his force and push his work, he failed to do so. Finally, on December 8, 1883, the contract was annulled and authority given to complete the work by open purchase and hired labor or contract. Some difficulty was experienced in getting a contractor who would undertake the work, on account of the lateness of the season, but finally a contract was made to complete the levee by February 1, 1884. Work was commenced under the new contract December 15, 1882, and pushed with great energy, though with inadequate force. Heavy and constant rains interfered materially with the progress of the work, and the time for completion was first extended to February 20, and afterwards to March 15, 1884.

"A portion of the embankment across the bed of Lake Saint Joseph continued to sink almost as rapidly as the earth was placed on it. Earth became difficult to procure, and had to be hauled or wheeled long distances.

"In addition to this, the levee commenced to slough badly at several points, so that it was impossible to keep it up to grade or put the bank in proper shape. The rains filled up the swamps, rendering it impossible to obtain earth to complete these sloughing places. As by a clause in the contract the United States agreed to furnish the contractor with workable earth, and this being impossible at the time, it was thought best for the interest of the Government to receive the work and make final settlement with contractor, which was done. Previous to this, when it became almost certain that the main line could not be completed, it was decided to endeavor to hold the old front line of levee, which, with the work done to keep out the high water of 1883, was in fair condition. The line of protection was nearly 2 miles in length, and on this line a hard fight was made against the rising river. The force was worked night and day, and the protection levee was raised, strengthened, and revetted with sacks and lumber. Two decked barges were obtained from Captain Marshall, and earth boated long distances. On March 15 the river had risen to 45.95 on the Vicksburg gauge, and an additional rise of not to exceed 18 inches was expected from the 'Yazoo wave.' The protection levee was raised and strengthened to meet this rise, which instead of 18 inches amounted to 3 feet, the crest of the wave being about 6 inches above the high water of 1882 at Hard Times.

"On March 20 the situation became desperate, as the river was brimming over the protection levee for 2 miles. On the night of the 20th breaks occurred in the levees above, causing a temporary fall of about 2 inches at Hard Times. The water pouring in through the breaks above inundated the country, and, owing to the peculiar topographical features of the locality, backed up against the land side of the new main levee, and on March 21 broke and washed it away for 200 feet. The river continued to rise, and eventually overtopped the protection levee, breaking it and the main line at numerous points. A survey of the levee has been made and the various gaps staked out. It is estimated that 40,000 cubic yards of earth will be required to close the gaps and complete the line. Under the recent allotment bids have been asked for to do this work and were opened September 27, 1884.

"HARDSCRABBLE AND BONDURANT.

"Work on this levee under contract was in progress October 31, 1883. The contractor failed to prosecute his work with due diligence, and there being no prospect of the work being completed in a reasonable time, the annulment of the contract was recommended and approved January 4, 1884. Authority was given to complete the work by hired labor and open contract. The lateness of the season and the amount of work to be done made the prospect for completion rather uncertain. In order to expedite matters and prevent even a temporary stoppage, the force engaged by the contractor was continued on the work.

"The contractor's camps and outfit having been seized by his creditors, permission was obtained from the legal custodian to occupy the camps and use the outfit. The construction of new camps was commenced and additional tools purchased. The progress of the work was greatly delayed by exceptionally bad weather, heavy rains alternating with severe cold snaps. The Hardscrabble Swamp was flooded and rendered almost impassable. From January 5 to 18 there were eleven days of continuous rain. Under the most extraordinary difficulties camps or quarters capable of accommodating 650 men were built, also master laborers' quarters, kitchen, bakehouse and oven, warehouse, and office.

"The road being impassable, a wooden tramway about 4,000 feet long was built from the steamboat landing to the new camps for the transportation of material and supplies. Previous to the annulment of this contract permission had been given the contractor to employ convict labor, and he had employed about 250 of these hands. The requisite authority having been obtained, they were continued upon the work, as it would have been difficult, if not impossible, to have replaced this organized force, who had their own quarters and tools. The free-labor force averaged about 400 men per day, and, considering the suddenness with which the work was undertaken, they were organized and handled to great advantage. On February 11 the men demanded an increase of wages and quit work. On February 13 their demands were acceded to and work was resumed, though with a slightly diminished force. On the day of the strike, February 11, the river was nearly over its banks and was rising rapidly. A light protection levee had been built immediately in front of the main line. On February 14 the river rose over the bank in the Hardscrabble Swamp, and after a hard fight broke the protection levee and ran through a gap of about 1,200 feet in the main line. This flooded the camps and caused a suspension of work. The river continued to rise and eventually overtopped all of the levee that was below grade. The lower end of this levee in the Bondurant field had been completed, but the water being on both sides of it, and being exposed to the washing of waves, a crevasse occurred. Since the decline of the river the bank at this point has caved very rapidly and the levee has gone into the river for a distance of about 2,500 feet. Hardscrabble levee was little damaged by the flood, only two small breaks occurring. It is estimated that 75,000 cubic yards of earth will be required to complete Hardscrabble. An entirely new line of levee, estimated to contain 35,000 cubic yards, will be required in the Bondurant field. Under the recent allotment proposals for the construction of each of these levees have been advertised for and were opened September 27, 1884.

"KEMPE BREAKS AND EXTENSION.

"Work on this levee under contract was in progress October 31, 1883. The contractor failed to prosecute his work with due diligence, and there being no prospect of the work being completed in a reasonable time, the annulment of the contract was recommended and approved January 6, 1884. Authority was given to complete the work by hired labor and open contract. For the same reason as at Hardscrabble, the contractor's force was continued on the work. The contractor's creditors seized his camps and outfit, and permission to use them was obtained from the legal custodian. The same causes that delayed the progress of the work at Hardscrabble prevailed here, only the locality being better drained, the damage was not so great. New camps or quarters capable of accommodating 600 men were built; also an office, warehouse, bake-house and oven, and kitchen. A wooden tramway about 4,000 feet long from the steamboat landing to the new camps was constructed. To facilitate the transfer of supplies and to place Hardscrabble and Kempe in close communication, as was necessary, a steam-tug was transferred from the work of improving harbor at New Orleans, and a small barge chartered. The portion of Kempe levee built by hired labor is probably the heaviest embankment of the kind in the State of Louisiana, considering its length. At one point the line of the embankment crosses a slough, and for about 1,200 feet it was impossible to procure earth, as the ground was covered by water from 2 to 3 feet deep. In order to procure material for the construction of the main line at this point, it was found necessary to build two side levees across the slough about 500 feet on either side of the main line and parallel to it. Two steam

pumping engines were procured and placed in position. One of them proved to be defective, but the other did good work, and the area between the side and main levee on the land side was soon pumped dry.

"Earth could then be obtained and men were put to work wheeling it into the levee. At the end of February the whole line of the Government work on this levee was well on towards completion, except the 1,200 feet in the slough. Meanwhile the river had risen to an alarming height, and the seepage water came in so rapidly that it was impossible to procure earth on the river side of the new levee. The Kempe protection levee, which had withstood the high water of 1883, was still in good condition, but on February 27 a force was put to work raising it as a matter of precaution. On March 11 the backwater coming down from the break at Hardscrabble flooded the new camps and the levee line, compelling a stoppage of work upon the main levee. The major portion of the force was paid off and about 100 men retained to work upon the protection levee. No danger was anticipated until Sunday, March 23. A heavy rain commenced in the morning and continued throughout the day, but a force of over 100 men was kept at work placing sacks and earth. The incessant rain finally caused the embankment to commence sloughing at several places, and at 1 p. m. an unexpected slough occurred, and notwithstanding every effort the river broke through. The tremendous current destroyed any work done to protect the ends of the break, which rapidly enlarged. Earth had been taken from the new main levee, all other available localities being covered with water, to assist in holding the protection levee. The water from the crevasse rushed over the main line at this point, washing it away and causing a break of about 800 feet in width. This did not add to the volume of water escaping from the river, as the new levee was incomplete at several points. A 'run-around' or new line of levee has been staked off to close this break, estimated to contain 25,000 cubic yards. Under the recent allotment, proposals for building this piece of levee at the crevasse have been advertised for, and were opened September 27, 1884. The balance of Kempe Levee, estimated to contain about 63,000 cubic yards, it is proposed to build by hired labor, and all preparations for the commencement of embankment construction have been made.

"LAKE CONCORDIA BREAKS.

"This long line of generally light embankment was completed by contract prior to the high water of 1883, which it stood without showing signs of weakness. It was reported to be in a dangerous condition at several points on March 14. The levee is composed of a loose, sandy soil, and is in many places exposed to the wash of the lake waves during high water. Measures were taken to protect the levee, lumber and sacks being used without stint. Notwithstanding every effort, however, eleven breaks occurred between March 23 and 26. The ends of these breaks were protected as far as possible to prevent further enlargement. The work necessary to close these breaks has been staked out, and it is estimated that 31,000 cubic yards of earth will be required for this purpose. Under the recent allotment proposals for this work were advertised for, and were opened September 27, 1884. Should there be any surplus funds from this allotment, it is intended to apply them, so far as they will go, to raising the grade of this levee, the work being rendered necessary owing to the elevation of the flood line, caused by the King's Point Cut-off above.

"GREEN'S TO FAIRVIEW.

"Work on this levee, under contract, continued without interruption or incident, and it was finally completed and accepted March 7, 1884. It was not damaged by the high water of 1884, although some work was required to prevent sloughing. It is now in good condition.

"ATCHAFALAYA FRONT (ATCHAFALAYA RIVER TO RED RIVER LANDING.)

"Some trouble was experienced with the contractor on this levee, he refusing to fill out certain shortages in the embankment. Finally he did the necessary work, and the levee was completed, and accepted December 31, 1883. With the exception of two sloughing places, the levee is in good condition. It is proposed to repair these two places by hired labor, the work being too small to do by contract.

"HOG POINT TO RACCOURCI (OLD RIVER).

"This levee was completed under contract prior to October 31, 1883. It is in good condition and requires no work.

"RACCOURCI CREVASSE.

"The levee was completed under contract prior to October 31, 1883, but during the high water of 1884 it showed signs of weakness, and required considerable work. A bad crayfish hole has developed, and it has proposed to cut this out, and make such other repairs as may seem necessary, by hired labor.

"STEWART'S CREVASSE.

"The levee was completed under contract prior to October 31, 1883. It is in good condition and requires no work.

"POINT COUPEE CREVASSE.

"This levee was completed under contract prior to October 31, 1883. A certain portion of the embankment across the bed of an old lake had been sinking. When the levee was received the sinking had apparently ceased, but upon the decline of the river after the high water of 1883 it recommenced, and in February, 1884, it was found necessary to do some additional work at this point to keep the levee up to grade; 13.4 cubic yards of earth were placed on the embankment, and up to date no further settling has taken place.

"SURVEY OF UNLEVEED FRONTS.

"A party under the charge of an assistant engineer was sent into the field in the latter part of November, 1883, to survey a line from Black Hawk Landing to Red River. The progress of the party was unusually slow, and the work was not completed until late in January, 1884. A preliminary line for a levee was surveyed and staked off for a distance of about 17 miles. The results of the survey indicate that a line of levee can be built with less cubical contents, and consequent cost, than had previously been supposed.

"CUT-OFF AT KING'S POINT.

"On May 11, 1884, the river made a new channel for itself across the above point. The cut-off is located on the Tensas front, about 4 miles below the town of Waterproof, and half a mile above L'Argent Landing, and shortens the river distance between those points about 12 miles. A ditch was cut across the point about the year 1855, and at every high water since that time the river flowed across the point through this ditch. The first indications of the river cutting its way through were observed on May 7 and 8, when the banks on both sides commenced caving rapidly, and by May 11 the cut-off was made. The ditch before the cut-off is said to have been about 50 feet in width by 20 feet deep. It is now the main channel of the river. The following table of gauge records shows the effect of the cut-off on the river at Kempe Levee, 10 miles above; at Waterproof, 4 miles above; and at Natchez, 21¼ miles below. It is to be regretted that no gauge record is attainable at any point nearer to the foot of the cut-off than Natchez. The river was nearly stationary just before the cut-off.

Gauge records.

Date.	Kempe levee.	Water Proof, Louisiana.	Natchez, Mississippi.
1884.			
May 7	5.25	....	44.90
8	5.21	....	44.90
9	5.25	....	44.85
10	5.21	....	44.85
11	5.05	....	44.90
12	4.95	3 in fall	44.95
13	4.75	2 in fall	45.00
14	4.55	2¾ in fall	45.05
15	4.40	2½ in fall	45.10
16	4.10	2 in fall	45.10
17	*4.05	*1¾ in fall	*45.10
18	4.10	2¼ in fall	45.15
19	3.85	1⅞ in fall	45.15
20	3.75	1⅝ in fall	45.10
21	3.75	1½ in fall	45.10
22	3.55	1 in fall	45.05
23	*3.60	*½ in fall	*45.10

* Heavy rain on May 17 and 23.

"It is greatly to be feared that the already rapid caving in the Kempe Bend will be accelerated, though the flood-line will be lowered. The last practicable line of levee has been built between the river and Lake Saint John at Gibson's Landing, below the cut-off. It is highly probable that one of the results of the cut-off will be to destroy this levee, in which case a long line of embankment will have to be built on the west bank of Lake Saint John, as has been done at Lake Concordia. The grade of the United States Lake Concordia Levee will have to be raised, as even before the cut-off the flood of 1884 proved it to be too low.

"PROTECTION AND PRESERVATION OF LEVEES, STATE AND UNITED STATES, DURING THE FLOOD OF 1884.

"On March 20, 1884, authority was given to do work on both State and United States levees on the Tensas Front, with a view to prevent further breaks. The following will give a general idea of the amount of work done: At Ashwood Levee (State), on Lake Palmyra, a great deal of work was done. From this point to Shipp's Bayou no work was done, as the levees were generally overtopped by the flood. Earth was boated long distances, and every effort made to hold Shipp's Bayou Levee (State). The report on Shipp's Bayou to Hard Times Levee describes the work at that point. From Hard Times to Bondurant's no protection work was undertaken, as the country inside the levees was deeply inundated from the Hardscrabble break, and several of the levees were overtopped by the flood. Between Bondurant and Kempe work was done on the Bruin's Bayou Levee and on the Lee Levee to prevent breaks. The work was successful, as no breaks occurred on this stretch. The history of the protection work at the United States Kempe Levee is given in the detailed report on that levee.

"Considerable work was done on State levees between Kempe and Lake Concordia, principally upon the L'Argent Levee. It showed great signs of weakness, and being composed of sand was washed badly by the waves. It was revetted and strengthened with lumber and sacks. Constant work alone saved this levee. The protection work on Lake Concordia is given in the report on that levee. From Lake Concordia to Red River work was done on State levees and on United States Green's to Fairview Levee at various points. On the Henderson-Ashley Levee (State) considerable work was done raising the embankment, which would have been overtopped by the flood.

"On March 26 the steamboat H. J. Dickey was chartered for the purpose of distributing material for the protection of the levees. She was loaded with 120,000 feet of lumber, 50,000 empty sacks, 120 wheelbarrows, and the same number of shovels. An assistant engineer was placed in charge, with directions to distribute material at threatened points between Point Coupee Levee and the head of the district.

"The limits of the protection were extended down-stream, first to a point 50 miles below Red River, and afterwards to the town of Plaquemine. Additional allotments of funds were made from time to time by the Commission for the purpose of protection. Assistant engineers were sent out and given charge of special districts. The work necessary for the protection of levees was done under their direction. It was at first expected that if the United States furnished the material the inhabitants would gladly furnish the labor, but in almost every case the Government both furnished the material and paid the labor. The Dickey distributed material from the head of Profit Island to Lehman's Store at the upper end of Green's to Fairview Levee. From the head of the Atchafalaya to Hog Point work was done at various points to prevent wash of waves and sloughing of embankment on the United States Levee. From Hog Point to Williamsport, on Raccourci Old River, no work was necessary, as the new United States levee was in good condition. From Williamsport around Raccourci Old River, and thence to Morganza, a great deal of work was done on State levees, which were badly riddled by cray-fish, lacking in crown, cross-section, and height. The United States Raccourci Levee in this stretch required a run-around to be built on account of a bad cray-fish hole.

"The new Bourgeois Levee (State) required a great deal of work, raising, reveting, and strengthening on the rear slope. The Ahren Levee (State), just above Morganza, required considerable work of the same kind. This stretch required additional work in June, when an additional rise out of the Red River again put the Mississippi up to dangerous height. Two crevasses occurred between Williamsport and the United States Raccourci Levee before the Government commenced work. From Morganza to Point Coupee Landing work was done on State levees, raising, revetting, and strengthening. The O'Malley Levee (State), immediately below Point Coupee Landing, had to be raised and revetted, and the rear slope being very soft, required constant watching. The United States Point Coupee Levee, commonly known as "Scott," remained in splendid condition, except at two points where some work was necessary to prevent sloughing. From Point Coupee to Waterloo the State levees required raising, reveting, and strengthening, which was done. At the Waterloo Crevasse considerable work was done to prevent further enlargement of the crevasse by protecting the ends of the levee. From Waterloo to Hermitage work was required

on the Grand Bay Levee in April, and again in June, as it was in a very threatening condition. From Hermitage to the head of Profit Island the State levees were in a dangerous condition and required considerable work in April and again in June. In the latter month a crevasse occurred just below Hermitage, but it was closed, the United States furnishing the material. When the protection work was extended to Plaquemine an assistant engineer was sent out to attend to any work that might be necessary. This was in the latter part of April, and at that time the river had fallen so that no work was necessary. In June, however, when the river again rose, some work was done. As indicating the amount of work done it may be stated that over 275,000 feet of lumber and 100,000 sacks were used on protection work only. In addition to actual labor on some of the levees, watchmen were put on day and night to give timely notice of any danger, and to prevent malicious persons from cutting the levees. The work accomplished has been of the greatest benefit, for without it the number of crevasses would undoubtedly have been greatly increased, and the cost of new levees to close them far exceeded the cost of the protection work.

"SURVEYS.

"The usual monthly estimates have been taken up for payment of contractors. Surveys of the actual condition of Shipp's Bayou to Hard Times, Hardscrabble and Boudurant, and Kempe levees, at the time of the annulments of the contracts, have been made. Work necessary for the closure of breaks in United States levees has been staked out in the field.

Gauge records from March 7 to April 17, 1884.

Date.	Vicksburg.	Saint Joseph.	Natches.	Red River Landing.	Baton Rouge.	New Orleans.
March 7	45.40	*42.25	....	42.35	....	....
March 8	45.65	42.45	44.60	43.00	33.50	0.42
March 9	....	42.65	44.60	43.30	33.50	....
March 10	45.75	42.65	44.65	43.70	33.60	0.66
March 11	45.80	42.65	44.75	44.00	33.90	0.56
March 12	45.80	42.90	45.10	44.30	34.40	0.46
March 13	45.95	42.90	45.10	44.50	34.70	0.14
March 14	45.95	43.00	45.15	44.70	34.90	0.08
March 15	45.95	43.00	45.25	44.80	34.95	0.08
March 16	45.95	43.00	....	44.80	34.70	0.29
March 17	46.00	43.00	45.30	44.80	34.50	0.29
March 18	46.50	43.35	45.80	45.40	35.30	0.09
March 19	47.10	43.80	46.10	45.60	35.28	0.08
March 20	47.85	44.66	46.45	45.80	35.30	0.17
March 21	48.40	44.35	46.85	46.05	35.50	0.06
March 22	48.90	44.40	46.95	46.35	35.70	0.06
March 23	48.85	44.63	47.25	46.65	35.90	0.09
March 24	48.85	44.90	47.40	46.90	36.20	0.09
March 25	49.60	44.86	47.40	47.00	36.00	0.08
March 26	48.80	44.84	47.40	47.10	35.95	0.17
March 27	48.70	44.70	47.30	47.15	36.00	0.17
March 28	48.55	44.52	47.25	47.25	36.00	0.25
March 29	48.40	44.40	47.20	47.30	36.10	0.25
March 30	48.25	44.81	47.15	47.30	36.10	0.25
March 31	48.60	....	47.10	47.30	36.02	0.42
April 1	47.75	44.31	47.00	47.25	35.90	0.50
April 2	47.55	44.19	46.90	47.20	35.80	0.59
April 3	47.30	44.08	46.70	47.10	35.75	0.66
April 4	47.10	43.88	46.60	47.00	35.70	0.58
April 5	46.90	43.71	46.50	47.05	35.65	0.62
April 6	46.75	43.59	46.45	47.05	35.70	0.42
April 7	46.55	43.40	46.30	46.85	35.45	0.66
April 8	46.40	43.40	46.15	47.70	35.30	1.08
April 9	46.20	43.30	45.90	46.55	35.20	....
April 10	46.00	43.10	45.75	46.40	35.03	1.00
April 11	45.80	42.90	45.55	46.25	34.95	1.17
April 12	45.70	42.75	45.45	46.20	34.95	1.08
April 13	45.60	42.60	45.35	46.05	34.80	1.08
April 14	45.50	42.50	45.25	45.90	34.60	1.08
April 15	45.50	42.40	45.25	45.80	34.55	1.17
April 16	45.50	42.30	45.10	45.75	34.40	1.25
April 17	45.35	42.20	45.00	45.65	34.35	1.32

REMARKS.

Crevasse at Davis Plantation, right bank, about 22 miles above New Orleans.
Crevasse at Morganza, right bank, between Red River Landing and Baton Rouge.
Crevasse at Belle Air or Mulatto Point, above Baton Rouge.
Crevasse at Point Pleasant, Buck Ridge, Shipp's Bayou to Hard Times, Lower Hard Times, and Bondurant's, between Vicksburg and Saint Joseph; at Kempe and Lake Concordia, between Saint Joseph and Natchez; at Batchelor's, on Raccourci, Old River, between Red River Landing and Baton Rouge.
Crevasse at Waterloo, between Red River Landing and Baton Rouge.
Crevasse at Lacour's, on Raccourci; Old River, between Red River Landing and Baton Rouge.

Extreme high-water readings on gauges.

[On some of these gauges the water was a little higher than here given, the last column being taken from the daily reports.]

Gauges.	1862.	1874.	1882.		1883.		1884.	
	Reading.	Reading.	Date.	Reading.	Date.	Reading.	Date.	Reading.
Vicksburg	51.00	45.70	Mar. 20, 21	48.75	Apr. 7	43.78	Mar. 25	49.00
Saint Joseph	....	....	....	44.50	....	....	Mar. 24	44.90
Natchez	50.30	45.58	Mar. 28, 29	47.75	Apr. 7	44.00	Mar. 24-26	47.40
Red River Landing	....	47.00	Mar. 27	48.50	Apr. 9	45.20	Mar. 29-31	47.30
Baton Rouge	....	36.15	Mar. 26	35.95	....	35.08	Mar. 24	36.20
New Orleans*	....	0.00	....	0.42	....	0.00	Mar. 18, 23, 24.	0.00

* Below high water of 1874. Low water of 1872 = 16.07 on New Orleans gauge.

"The above table of gauge records during the flood of 1884 has been compiled and is of interest. The almost imperceptible effect of crevasses on the gauges is a very marked feature. It will be noted that notwithstanding over sixty crevasses, large and small, between Vicksburg and Natchez, the gauge at the latter point rose with great regularity to maximum high water, and then fell with equal regularity. This may be accounted for by an extraordinary local rainfall over the Big Black Basin, which drains into the Mississippi, principally between the above points. From March 17 to 23 the measured rainfall at Vicksburg was 4.19 inches, and it is claimed that an equal amount fell at Baton Rouge, being general throughout the Big Black Basin. The area of this basin is, according to Humphreys and Abbott, 7,260 square miles. A rough computation, based on the foregoing figures, gives 67,000,000,000 cubic feet of water, less loss by evaporation, absorption, &c., emptied into the Mississippi below Vicksburg on the crest of an extreme flood. Whenever these circumstances recur, the result, so far as existing levees are concerned, can readily be surmised.

"In concluding, I would express my obligations to the various assistants which you have assigned to me from time to time, and to the clerical force on those levees being built by hired labor, for the energy and industry shown in the discharge of their duties.

"Very respectfully, your obedient servant,

"H. S. DOUGLAS,
"*Assistant Engineer.*

"Maj. AMOS STICKNEY,
"*Corps of Engineers, U. S. A.*"

MONEY STATEMENT.

	Atchafalaya Front.	Tensas Front.
Allotted	$146,000 00	$537,160 00
Drawn	134,000 00	447,160 00
Not drawn	12,000 00	90,000 00
On hand assistant treasurer, New Orleans, September 30, 1884	7,091 60	2,773 37
In hands of assistants	....	200 00
Expended to September 30, 1884	126,908 40	444,186 63
Balance October 31, 1883	....	174,529 19
Balance due from appropriation October 31, 1883	2,947 22	....
Received since	34,000 00	21,000 00
Expended since October 31, 1883	23,961 18	192,555 82
Balance on hand September 30, 1884	7,091 60	2,973 37
Total allotments	146,000 00	537,160 00
Total expenditures	126,908 40	444,186 63

IMPROVEMENT OF MISSISSIPPI RIVER AT NATCHEZ AND VIDALIA, MISSISSIPPI AND LOUISIANA.

No work has been done during the past year, ending October 1, 1884, there being no funds allotted, and the amount expended from the small balance on hand has been for payment of watchmen in care of engineer property and expenses of survey party and office work. Information having reached this office during the latter part of

March that a cut-off was threatened at Cowpens Bend, an assistant engineer was sent to investigate the matter, and reported from information received on the ground, the river at the time being at too high a stage to permit of a close examination, that the banks along Cowpens Bend and below Bullitt's Bayou were caving considerably, but the current across the bend indicated no greater velocity at any one point than another, and that he could see no immediate danger. On the 25th of June, the river having receded within its banks, instructions were given for a survey to ascertain the changes in the bends, and establish points of reference to determine future changes. This survey, compared with the Commission's survey of February, 1883, shows that a very considerable caving has taken place at Palo Alto Point, above Vidalia, permitting the current to strike lower down in the Natchez Bend, and considerable caving in Giles Bend, and very much more in Marengo Bend, below Bullitt's Bayou. The most dangerous feature of these changes is the wearing off of Palo Alto Point and general dropping down of the bend. In letter of September 17, 1884, to the president of the Commission it was recommended that as soon as funds were available the erosion of the point should be checked by the construction of two spur-dikes above the point; work of protection to be afterwards extended up the bend and in Giles Bend, based on the experience gained by the first two dikes, which it is believed will hold the point. These two spur-dikes, it is estimated, can be constructed for $30,000. Spurs for the protection of the banks around the bends can probably be constructed for $10,000 each, and if this system proves as successful as is hoped, each spur will protect an average of about 1,000 feet of bank. In some parts of the bends the intervals between spurs would of course be less, depending upon the curvature. The length of bank to be protected is about 16,000 feet in Giles Bend, and about 39,000 feet in Marengo Bend, a total of 55,000 feet, which, at $10 per foot, would require an expenditure of $550,000. To this must be added the cost of plant, which from the experience of New Orleans Harbor would be about $50,000, making a total of $600,000. If it should be found necessary to cover the banks with mattress work, the cost of $18 per linear foot, as originally estimated by Major Benyaurd, is not excessive. The spur system is worth trying, and the plant necessary would be entirely suitable for the mattress system if it were necessary to change.

Approximate estimate of the cost of the work for the protection of the banks above Natchez and Vidalia, $600,000.

MONEY STATEMENT.

Transfer, September 9, 1882	$7,529 09
On hand, assistant treasurer, New Orleans, September 30, 1884	2,672 92
Expended since September 9, 1882	4,856 17
Balance October 31, 1883	5,331 42
Expended since	2,658 50
Balance on hand September 30, 1884	2,672 92
Total appropriated	90,000 00
Total expended	87,327 08

MOUTH OF RED RIVER, LOUISIANA.

The survey of the vicinity of the mouth of Red River, which was in progress at date of last annual report, was continued till January 23, 1884, when the party was withdrawn from the field.

The details of the work are given in report of Assistant Engineer A. O. Wilson, and copies of the maps have been forwarded to the secretary of the Commission.

A project for the rectification of the mouth of Red River and the Atchafalaya River was submitted to the Commission December 15, 1883, as follows:

"PROJECT FOR THE RECTIFICATION OF THE ATCHAFALAYA RIVER AND MOUTH OF RED RIVER.

"UNITED STATES ENGINEER OFFICE,
"*New Orleans, La., December* 15, 1883.

"SIR: I have the honor to present for the consideration of the Commission a project for the rectification of the Atchafalaya River and mouth of Red River.

"This problem is one that has engaged the attention of many engineers, and while a number of plans for its solution have been proposed none has ever been definitely

adopted as meeting all the requirements of the case, or satisfactorily overcoming all of the difficulties.

"Before discussing any plan for improvement it is well to briefly state the condition of the river in this vicinity and the main points to be considered in any plan for so changing these conditions as to permanently overcome all the difficulties.

"The Mississippi River in approaching the mouth of Old River from above has its deep-water channel near the right bank until it arrives within less than a mile of Old River; the channel then crosses quite abruptly to the left bank, which it follows until it has passed Old River, when it again returns to the right bank.

"Between the points of its leaving and returning to the right bank lie the Angola Bar and the mouth of Old River. The first crossing with the consequent bar formation below it is caused partly by the progressive caving of the right bank, as shown at 'A' on the map, but probably also to a great extent by the deposit of sediment consequent upon the escape of water through Old River, and over the banks. As this bar occurs in the concave side of a bend of the river, it would seem as if it might be entirely removed by a proper directing of the current and regularization of the bend shore, and this without danger of reformation if the deposit caused by escaping water was stopped by confining the water. This bar at times is an impediment to navigation and must have some influence in retarding the passage of floods.

"The oscillations of the water surface at Red River Landing are between the low water of 1872, which is 0 on the gauge, and the flood height of 1882, which is 48.50 on the gauge. Owing to the variation of the relative levels of the Mississippi and Red rivers, the water at times passes, from the former towards the Atchafalaya through Old River, sometimes in large quantities, at other times the direction of current is reversed; but each year the flow increases in amount from the Mississippi, and for longer periods of time, caused by the enlargement of the Atchafalaya. The difficulties of the present situation, then, as far as the Mississippi River is concerned, may be briefly stated to be the Angola Bar, and the deflection of the water of the river in ever-increasing quantities down the Atchafalaya, and we might imagine that in a sufficient number of years the bar would grow up to be the left bank of the river, and the Atchafalaya would become the Mississippi.

"Red River after passing Alexandria flows through a channel which has the high land of the Point Maigre Hills on the left and the low ground of the Lamourie swamps on the right, until it reaches the high ground of the Avoyelles prairies on its right bank. Then for a distance of about 9 miles of its course the river flows in a valley between hills which has an average width of about 2 miles. It then turns sharply to the right, and for 10 miles more has the high ground on its right At this point, near Ware's Landing, the river turns sharply to the left; leaves the high ground, and being joined about 33 miles farther down by the Black, continues till it arrives at its old mouth, in an old bend of the Mississippi River, at a distance of about 9 miles from the latter river. At this point the water has two channels which it may follow, one being to the left of what is now known as Turnbull's Island and called Upper Old River, the other to the right of the island and called Lower Old River.

"At high stages the water flows both ways; but the upper channel is filling up, and at low water none passes in. The water of the Red passing down Lower Old River reaches the head of the Atchafalaya about 3 miles below the head of Turnbull's Island; and here again there are two channels, the Atchafalaya, which receives the greater part of the Red, sometimes all, and the continuation of Lower Old River, which at times carries a part of the Red to the Mississippi, a distance of 6 miles, and sometimes brings water from the Mississippi to the Atchafalaya.

"The right bank of the Red, from Alexandria to a point near the Avoyelles Prairies, is leveed; below that point there are no levees.

"Near this high ground on the right bank a small stream called Choctaw Bayou joins the Red, draining the Lamourie Swamps into the Red when the latter is low, but in flood season taking water from the Red and discharging it into Pearl Lake, from which it escapes southward through bayous and over the low land. Black River, entering the Red from the north, brings in its valley in time of flood, besides its own drainage water, all of the water that escapes from the Mississippi over its right bank as far north as the Arkansas River, with the exception of that which returns to the Mississippi at certain points. The length of Red River from Alexandria to the Atchafalaya is about one hundred and ten miles. The high water of 1882 at Alexandria was 77.8 feet above the zero of the Barbres Landing gauge at the head of the Atchafalaya. The same high water at the latter point was 50.28 feet above the same zero. The high-water slope then was 27.52 feet, or about .25 foot per mile. The low water of 1881 at Alexandria was 39.25 feet above the Barbre's Landing zero. The low water of 1881 at the latter place was 1.2 feet below that zero. The low-water slope then was 40.45 feet, or about .368 foot per mile. In 1881 the water was the lowest and in 1882 the highest ever known. Owing to the variations in the r lative levels of the water in the Mississippi and the Red, the slope of the lower part of the Red is subject to violent changes. When the Red is at a comparatively low stage the surface at the head of the Atchafalaya

may vary as much as 12 or 14 feet, and at all stages its surface level depends greatly upon the condition of the Mississippi. The consequence of this is that at times the discharge area of the lower portion, increased by the backing up of the Mississippi, is much greater than at points above, the velocity is sharply checked, and a deposition of sediment must result. This deposition is probably most marked in the vicinity of the mouth of Black River, for up to that point the river is considerably deeper and wider than above. When the Mississippi falls, the slope of lower Red River is increased very considerably, the velocity is greater, and the deposit begins to cut out. Sometimes this increase of slope is so rapid that the cutting out of the deposit does not keep pace with it, and then we have the curious condition noted in Major Benyaurd's annual report for 1882; that is, a slope of only .037 foot to the mile below Black River, and a slope of .8 foot to the mile for the first 8 miles above Black River, the latter slope creating such velocity of current that steamboats could only stem it by using lines fastened to the shore. An examination of the level notes of Major Benyaurd's survey, however, discloses a much greater slope in the first 2 miles above Black River, viz, 2.12 feet to the mile, and as the width of cross-section in these 2 miles varied from 200 to 300 feet, it is probable that at some points a considerably greater slope obtained. In the flood of 1882 the total discharge of Red River escaped over its south bank, the lower end of the river being filled with Mississippi crevasse water. The present difficulties, then, of lower Red River are a continual and sometimes rapid and considerable change of slope and sufficient outlet for its floods, the latter caused by its lower channel being filled with Mississippi crevasse water.

"Lower Old River, the connecting link between the Mississippi and the Atchafalaya and Red, being an old channel of the Mississippi, has a high-water width equal to the Mississippi for most of its length, and from the head of Turnbull Island to the foot has the form of a flattened S. From the foot of the island to the Mississippi, a distance of about 1 mile, the channel is nearly straight, with a high-water width of about 800 feet, the remainder of the Old River channel having silted up. Although at times the current through Old River is quite rapid, sometimes in one direction and sometimes in the other, it is often sluggish, and this may occur whether the Mississippi is high or low. When the Mississippi water, above the low stage, enters Old River highly charged with sediment, it immediately loses a great part of its velocity, and drops a large part of its sediment at the mouth. As the water advances beyond the foot of Turnbull Island it spreads out into the wide channel, loses more velocity, and drops more sediment. If the Mississippi is high enough, it spreads over Turnbull Island, dropping most of its sediment near the banks. The island is then a large bowl, whose rim constantly grows higher, and a considerable part of the flood water remains after the flood subsides, forming ponds which contain water at all times. As the low-water season advances, and the rivers fall, Old River drops into a low-water channel. The deposit at the mouth comes up so near the low-water surface that boats cannot pass unless a channel has been dredged through. The water from the Mississippi passing through the straight reach hugs the island shore, which is the concave side of the bend, for about two miles, when it crosses to the other shore, which then becomes the concave side. The low land lying between the high banks, and which forms the low-water bank on one side, like all banks which are overflowed by sedimentary streams, slopes down from the channel. These low lands, then, have ponds of standing water after the stream has dropped below its low-water banks. The current through Old River makes a well-defined low-water channel, less marked at the crossing, and scours out a considerable part of the high-water deposit. As the water in the river falls, the water in the ponds on either side percolates through the soil and drains into the river. If the river falls slowly it sustains its banks while this draining is in progress, but if it falls rapidly, the drainage water comes under greater head, and the substrata of the banks being converted into a semi-liquid material, and being unsupported by pressure from the river, is squeezed out into the river by the weight of the superincumbent earth. This action is so decided in this vicinity as to entirely dam up the river for hundreds of feet when the conditions are favorable for it, as they were this year.

"The present difficulties in Old River, then, are the bar at the mouth, the sliding banks, and the insufficient low-water channel depth at the crossing.

"The Atchafalaya River, previous to about 1846, was so blocked up with raft material that comparatively little water passed down its channel, and the banks below Simmsport were never overflowed except from backwater. The State of Louisiana undertook the work of removing the raft to make a navigable channel through. From the time that the channel was cleared the river has been steadily enlarging. As the river began to carry the flood-waters of Red River and crevasse water from the Mississippi, its flood surface gradually became higher and higher. At first small levees were built to protect the adjacent country; then larger ones, and finally levee building was given up in despair, and the plantations below a point about 21 miles on the east bank and 30 on the west bank from the head of the Atchafalaya, were abandoned.

"This enlargement of the Atchafalaya is still in progress. In the flood of 1882 the upper part of the river carried nearly one and one-half times the entire flood dis-

charge of Red River, estimating the latter at 200,000 feet per second; since that time the cross-section has still further enlarged both in width and depth. In low water, owing to the great depth, the slope and velocity are exceedingly small, and the extreme low-water surface at the head of the river is but 1.86 feet above Gulf level. The only obstructions to low-water navigation are numerous snags and remains of raft. In flood the slope of the upper part of the river is quite sharp, in 1882 being .6 feet to the mile at the head. Owing to the ragged nature of the banks and bottom, caused by the immense and irregular caving and the sharp bends, the river in flood is full of whirlpools and eddies and sudden changes of direction of current. These not only make navigation extremely dangerous, but diminish the capacity of the channel for discharge. The difficulties to contend with in this river, then, are its constant and rapid enlargement threatening to take a large quantity of the Mississippi River and devastating the country below by its enormous overflows, the lower river being unequal to the discharge, dangerous high-water navigation, and snag obstructed low-water navigation.

"The latter difficulty, however, is not a part of the problem before us, except in such plans as contemplate the passage of that part of the river by the commerce of the Red, Black, and Ouachita.

"Having thus briefly stated the situation and noted the principal features of the problem to be solved, I will note the different plans that have been proposed for its solution, without entering into any extended discussion of them at this time. But before proceeding further it is proper to note another feature of the case, which in former years was a very prominent one. It is the drainage of the crevasse water escaping from the Mississippi in floods all along its right bank from the Arkansas to the Red. In 1882 the maximum escape was estimated to be 500,000 cubic feet per second. It entirely filled the Atchafalaya; sent 300,000 feet over the country between the Mississippi and Bayou Bœuf, and returned about 100,000 feet to the Mississippi through Old River. The average of this water, which in previous years was a matter of vast importance, is rapidly dropping out of the problem, and in the next year will probably be almost insignificant by reason of the leveeing of the entire Mississippi front from the Arkansas to the Red.

"The following plans have been proposed:

"(1) To close the Atchafalaya, turning the whole of the Red River with its floods into the Mississippi, and making a connection with the Atchafalaya for its commerce by canal and lock at Plaquemine.

"(2) To separate the Red and Atchafalaya by a low-water dam, turning Red River down upper Old River. This would also necessitate a canal and locks at Plaquemine.

"(3) Close the mouth of Old River, thus making the Atchafalaya a continuation of the Red, opening communication from the Mississippi by canal and lock at Plaquemine. This plan also contemplates, I believe, the building of a levee from Black Hawk to Red River, so as to leave no opening.

"(4) Leaving the rivers as they are and opening a low-water communication by canal and lock at Plaquemine.

"(5) Making a cut from Red River near the mouth of Bayou Cocodrie, about 15 miles above Barbre's Landing, to the Mississippi near Black Hawk, with either a high or low-water dam across the Red below the cut.

"(6) To leave the rivers as they are, and make a low-water connection between the Mississippi and Red by means of a canal and lock at Black Hawk.

"The first plan has been rejected by the Commission as being too dangerous in pouring the floods of the Red into the Mississippi when the latter was at flood height.

"The second plan while necessitating the costly construction of canal and lock at Plaquemine for the commerce of the Atchafalaya, would leave the lower part of the Red subject to even greater variations of slope from the backing up of the Mississippi than is now the case, and would not prevent the loss of water from the Mississippi down the Atchafalaya.

"The third plan would change the route of commerce for the Red, Black, and Ouachita, would necessitate considerable improvement in the Atchafalaya, and would, probably, be the most costly.

"The fourth plan would not prevent the loss of water from the Mississippi down the Atchafalaya.

"The fifth plan would not prevent the loss of water from the Mississippi down the Atchafalaya, and, as stated in Major Benyaurd's report, would make an uncertain connection between the Mississippi and the Red, besides necessitating the Plaquemine lock and canal for connection with the Atchafalaya.

"The sixth plan is subject to the same objections as the fifth, except that the connection between the Mississippi and Red would not be uncertain.

"The plan that I have to present is as follows:

"Divide Red River at the head of Turnbull Island, one branch to be called Red

River, to be conducted through upper Old River to the Mississippi; the other branch to be called the Atchafalaya, to be conducted down lower Old River into the Atchafalaya. Each of these branches to have an extreme low-water surface width of 400 feet, bottom width of 320 feet, side slope of 1 on 10, depth of 4 feet. As this is to

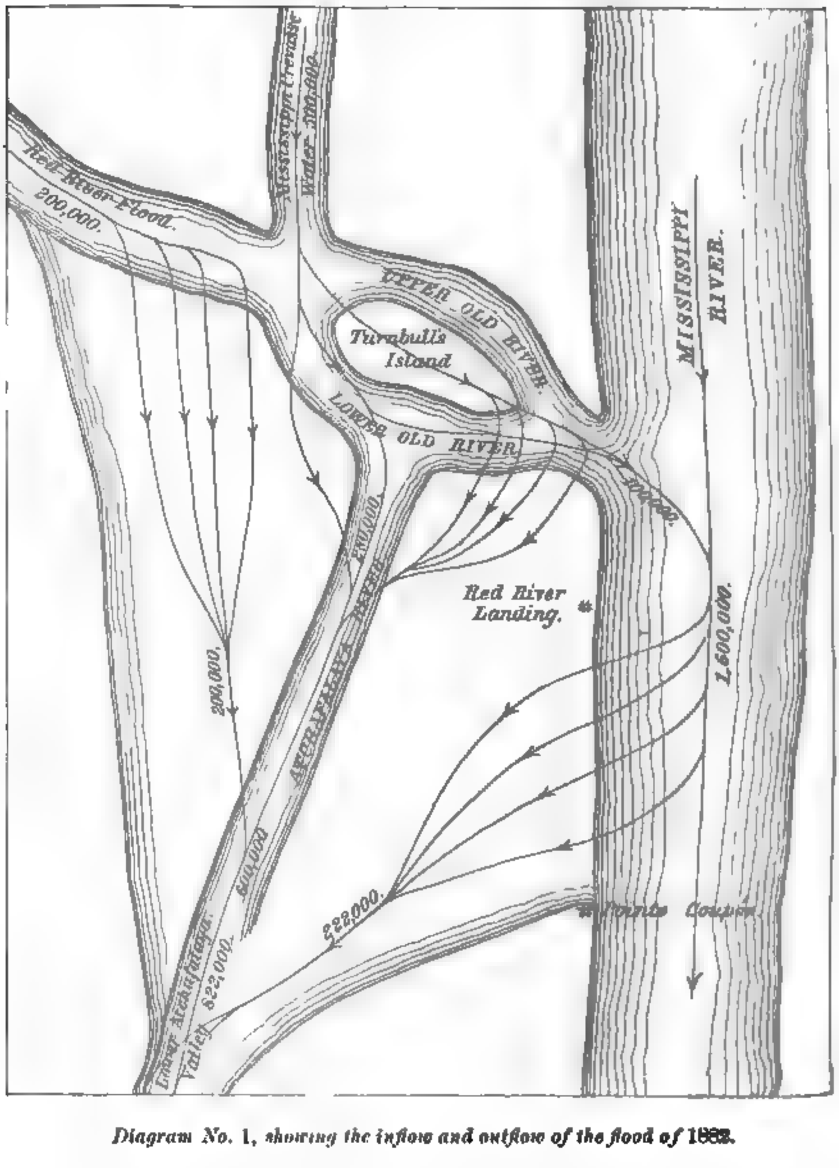


Diagram No. 1, showing the inflow and outflow of the flood of 1882.

correspond to the lowest water known in the Mississippi and the Red, and supposing them to be coincident, there would be but very few days, and only at intervals of years, when the depth would not be greater. The low-water surface at the head of Turnbull's Island to be 10 feet above the low-water surface of the Mississippi at the mouth. This would give a slope of 10 feet in 9 miles through upper Old River, in the extreme case of low water, and would give a velocity of 2.1874 feet per second, or 1.49 miles per hour; the low-water slope down the Atchafalaya to be 2 feet to the mile, and the bottom of the river to be brought parallel to this surface. This

would give a velocity of 2.54 feet per second or 1.73 miles per hour. I would propose to bring the bottom of the Atchafalaya up to this grade by the process of silting up, to be accomplished by the construction of submerged dams of brush and stone, which would be placed at intervals of about 1 mile, the silting between the dams to be assisted by double rows of submerged piles with foot-mats at intervals of, say, one-quarter of a mile. The sides of the low-water channel to be defined by longitudinal dikes of low mattress work where necessary. The channel down upper Old River to be likewise defined, with occasional brush sills across the bottom, to regulate the

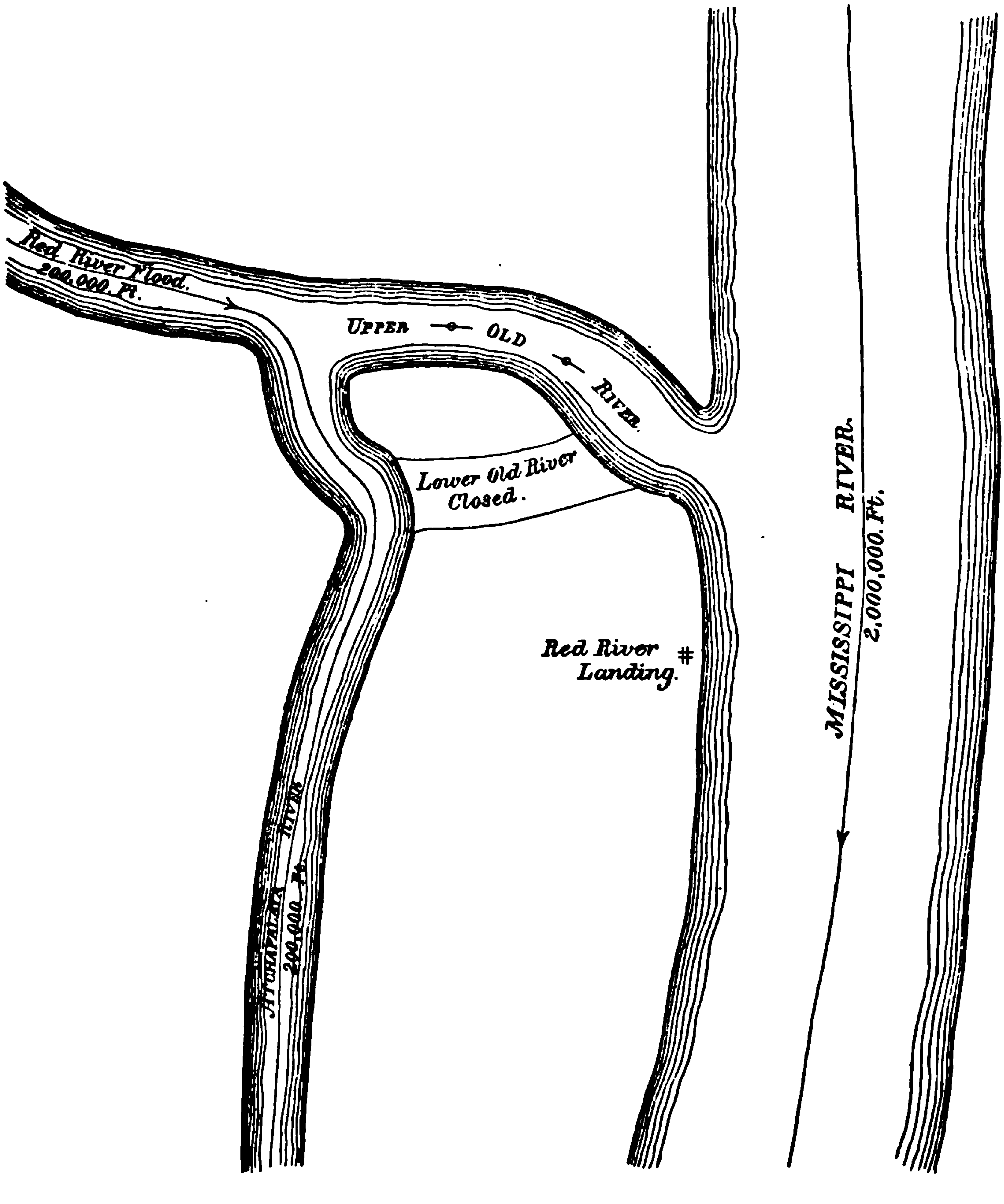


Diagram No. 2, showing the management of flood after improvement.

depth, and cross-dikes of piles to confine the channel. Assuming that the water in the Atchafalaya might fall to 2.0 on Barbre's gauge, which is .8 foot lower than ever known and only 1.0 foot above Gulf level, the allowance being made to provide for the lesser flow into the Atchafalaya, the total low-water fall from the head of Turnbull Island to the lower end of the improved channel would be 12 feet, and would extend 6 miles from the head of the island to a point about 3 miles below Barbre's Landing, which would be about 1½ miles above the beginning of the levee on the right bank. Lower Old River I would close gradually, partly by permeable dikes to

cause deposit, the final closure to be by building a levee, if it should be found necessary.

"This plan is based upon the leveeing of the Tensas front, which now seems assured. Now, let us apply the various conditions of the present state of affairs to this plan to see how far it will meet the requirements of the case.

"With regard to the Mississippi River, none of its water would pass down to the Atchafalaya ordinarily, and at no time could it pass in very great quantity or for any extended period of time. As a consequence of this there would be no reason for the existence of the Angola Bar if the regular curvature of the bend of the river were compelled.

"With regard to Red River. The violent changes of its lower slope would be transferred to upper Old River, and be limited to a confined regularized channel which would maintain itself. The building of the levees along the Tensas front, thus preventing the escape of any of the Mississippi River water, fortunately simplifies, to a very great extent, the matter of the disposition of the Red River floods. To give a clear understanding of the flood condition of the rivers under discussion, I would call attention to the two preceding diagrams. No. 1 illustrates the overflow and outflow of the water in the vicinity of lower Red River during the flood of 1882, the highest ever known. No. 2 illustrates the same with the river improved upon the plan that I present and supposing the Tensas Front leveed:

"During the flood of 1882 it was estimated, upon surveys made under the direction of the Commission, that the maximum escape of water from the Mississippi River between the Arkansas and the Red, after deducting the amount that returned to the Mississippi, was 500,000 cubic feet per second; and calling the flood of the Red 200,000 feet, it would be noted that 700,000 feet of water per second crossed the latitude of lower Red River west of the Mississippi; of this amount more than 200,000 feet flowed over the right bank of the Red, west of Old River, none of Red River water making its appearance in the Atchafalaya above a point about 3 or 4 miles below Barbre's Landing; 280,000 feet passed into the channel of the Atchafalaya at its head, and enough more passed over the right bank of Lower Old River to make a total of about 600,000 feet flowing past the latitude of Red River Landing west of the Mississippi. These figures are from Commission surveys. The remaining 100,000 feet of the inflow passed into the Mississippi through Lower Old River, Upper Old River, and across Turnbull Island and the country just north of Upper Old River. The discharge of the Mississippi at Red River Landing was about 1,600,000 feet.

"After passing Red River Landing the escape from the Mississippi through crevasses on the right bank down to Point Coupee was 222,000 feet, which went to swell the flood of the Atchafalaya Valley, making the total Atchafalaya discharge 822,000 feet. With the Tensas front leveed, the 500,000 feet of crevasse water would be confined to the Mississippi channel; there would then be but 200,000 feet for which outlet must be provided west of the Mississippi, supposing it inadmissible to discharge any of Red River flood into the Missiissippi. Let us suppose a Mississippi flood to reach the flood height of 1882 at the mouth of Old River. This would be about 48.5 referred to Barbre's Landing gauge, that gauge having its zero 0.3 feet above Red River Landing gauge, and the flood slope being about 0.3 feet from Old River to Red River Landing. Now, to prevent any water escaping from the Mississippi, or any passing into it, the water surface of the head of Turnbull Island must be 48.5 referred to the Barbre's gauge, and the channel down the new Atchafalaya must have sufficient capacity to carry 200,000 feet with the water surface at that height. A computation of the discharge through the new cross-section at what is known as section 4, near the head of the Atchafalaya, and about the narrowest section, shows that the discharge will be 200,000 feet with the water surface at that point at an elevation of 48.15, which would give a fall .35 foot from the head of Turnbull Island to section 4, which is ample slope for that part of the river as determined by computation at what is known as section 8, Old River (see map).

"In the computation for section 4, the assumption is made that the slope will be at least equal to the flood slope of 1882. Athough the surface at section 4 is to be 8 feet lower than 1882, I think there can be no doubt that the slope will at least equal that of 1882, when we consider that the lower Atchafalaya Valley is to carry only 200 000 feet, while in 1882 it carried 822,000 feet. As a further proof of this I will cite the fact that whilst the flood surface of 1874 was 3.5 feet lower than the flood surface of 1882 at Barbre's Landing, it was about 7 feet lower at the mouth of Bayou Courtableau, 50 miles distance, as established by one of my assistants. The following computations are made to exhibit the discharge capacity of the Atchafalaya River:

"Atchafalaya, section 4 (survey of 1881), Humphreys and Abbot's formula: Water elevation, top of flood, 49.9, Barbre's gauge: $A = 43,100$: $W = 1,038$; $P = 1,094$; $S = .00011364 = .6$ per mile; $V = 6.76$; $Q = 291,356$.

'Assistant Engineer Ewens' discharge measurements made at a point above section 4 (March 31, 1882): $A = 38{,}500$; $W = 1{,}030$; $V = 7{,}288$; $Q = 280{,}613$.

'Proposed Atchafalaya section 4, with submerged dam. Water elevation 48.15, Barbres gauge: $A = 33{,}769$; $W = 1{,}070$; $P = 1{,}100$; $S = .00011364 = .6$ per mile; $V = 5.919$; $Q = 199{,}879$.

"The computation of the discharge through section 4 (survey of 1881) is based on the actual flood slope of 1882, as established by levels of H. W. Reynolds, under the direction of the Commission. This computed discharge is 3.8 per cent. greater than the actual measured maximum discharge as determined by Assistant Engineer Ewens at a section a short distance above. An examination of Mr. Ewens' notes shows that this section on December 23, 1881, when the water was at the lowest stage at which a discharge was measured, was 3.5 per cent. greater than on March 31, 1882, the date of the maximum discharge.

"It is almost certain, then, that section 4, only a short distance below it, suffered a similar decrease of area. The above computed discharge of section 4, decreased by 3½ per cent. of 280,600, would give 281,535 cubic feet, showing that the computed discharge at section 4 agrees very closely with the measured discharge. This, then, allows us to make the necessary comparison of the discharge capacity of this section as it was in the flood of 1882, and as it would be with the proposed improvement. In the flood of 1882 it discharged 280,600 feet per second. With the proposed raising of the bottom and with water surface lowered nearly 2 feet, it would discharge 199,879 feet, that is, the entire Red River flood.

"As this section is shown in the table in Major Benyaurd's annual report for 1882 to have the smallest area of any of the sections in the first three miles of the Atchafalaya, any other section would have a greater capacity for discharge.

"The following is a computation of the slope at section 8, Lower Old River, requisite for a discharge of 200,000 feet, with bottom raised:

'Section 8, Lower Old River (survey of 1883): Assumed water surface, 48.5, Barbre's gauge, with submerged dam. Assumed $Q = 200{,}000$; $A = 97{,}139$; $V = 2.0589$; $W = 2{,}920$; $P = 2{,}935$: Computed $S = .000001596 = .0084$ foot per mile.

"The above computed slope of about .01 foot to the mile would consume only .025 foot of the .35 foot between elevation 48.5 at head of Turnbull Island and 48.15 at section 4, leaving .325 foot slope for the half mile above section 4. As the average cross-section width in this half mile is about 1,300 feet, the greater part of this slope would be utilized in overcoming the bend resistance.

"It would then be seen that with a flood equal to that of 1882 the flood height at Barbres Landing would be reduced nearly 2 feet with the improved channel, and the flood height on the Lower Atchafalaya would probably be reduced to such an extent that only small levees would be required to prevent overflow.

"As the theory upon which the Commission is proceeding in building levees supposes a reduction of flood heights of the Mississippi, after the completion of the levees, the flood surface at the mouth of Old River would be lower than above given, if the theory is correct, in which case a part of the Red River flood would be discharged into the Mississippi, with a consequent lowering of the Atchafalaya surface.

"The same effect would be produced if the flood of the Mississippi and Red were not coincident.

"With regard to Old River: During the process of forming the new channels Lower Old River would necessarily be used. I would propose to keep it in navigable condition by a system of dikes, to direct and confine the low-water channel without causing too great a scour. The dikes from the foot of the island to the Mississippi might be a part of the permanent improvement, and the scour of the current passing either way through them would probably maintain a navigable channel through the bar at the mouth. I would remedy the sliding banks difficulty, partly by moving the channel farther away from the worst bank near Ash Cabin, and by making a sufficient number of drains to prevent water standing between the banks at a higher level than the river. When Upper Old River became the navigable channel, its confined limits, regular cross-section, and constant current would maintain it in good condition and sweep out its depth through the bar at the mouth. The sliding banks are not so troublesome as in Lower Old River, and the standing pools in the low middle ground would soon disappear by compelling the silting up of regular banks with slopes towards the river.

"With regard to the Atchafalaya, the fixing of a stable bottom and immovable thalweg would stop the immense and irregular caving of the banks in the improved channel; they would become more regular in outline by the wearing away of projections and silting up of cavities, and as a consequence the dangerous eddies and whirlpools would disappear or be greatly lessened. The natural channel below the improvement, having less water to carry, would not enlarge, and the banks would gradually become more regular, small levees would confine the floods, and the deserted plantations would again be cultivated.

"The project that I present thus appears to meet all of the conditions of the problem and overcome the difficulties of the present situation, giving a permanent and sufficient improvement of the navigation without disturbing the present routes of commerce, and making proper provisions for flood discharge. If any of the conditions to be met here escaped my observation, I have no doubt the Commission will discover them. In the prosecution of this plan, I would propose to commence the work at the lower end on the Atchafalaya, constructing the dams in the order of 1, 3, 5, 7, as it might be found that 2, 4, 6 would not be necessary, or their cost lessened by decrease of height from the silting up of the bottom. I would not at first build the dams to their ultimate height, so as to prevent any sudden and harmful increase of slope.

"According to the testimony of M. Jacquet, chief engineer of Ponts et Chaussées (see Colonel Merrill's translation on the Improvement of Non-Tidal Rivers, page 159), submerged dams may be brought to within 8 feet of low-water surface without causing the least injurious disturbance on the surface.

"The following is an approximate estimate of the cost of this work:

ATCHAFALAYA RIVER.

7 submerged dams of brush and stone, containing 7,365,719 cubic feet, at 4 cents	$294,630
8 miles = two-thirds of entire distance on both sides of channel from Turnbull's Island to lower end of improvement = 42,240 feet low longitudinal mattress dikes of brush and stone, 3,168,000 cubic feet, at 4 cents	126,720
Cross lines of submerged piles, 13,600 linear feet, at $5	68,000
Excavation for channel, 860,000 yards, at 10 cents	86,000
	575,350

UPPER OLD RIVER.

12 miles = two-thirds of entire distance on both sides of channel from head of Turnbull's Island to the Mississippi = 63,360 feet low longitudinal mattress dikes of brush and stone = 4,752,000 cubic feet, at 4 cents	$190,080
36 brush and stone sills across channel, 1,080,000 cubic feet, at 4 cents	43,200
41,000 linear feet cross-dikes, at $4	164,000
Excavation for channel, 408,500 yards, at 10 cents	40,850
	438,130

CLOSING LOWER OLD RIVER.

4 dikes = 12,000 linear feet, at $4	$48,000
Atchafalaya River	675,350
Upper Old River	438,130
Lower Old River	48,000
Aggregate	109,480

"As Lower Old River will necessarily be used for communication with the Red and Atchafalaya (pending the completion of work under any plan that might be adopted), I recommend that the low-water channel be directed and defined by a system of dikes about as indicated on tracing-sheet 2, and that a Menge dredge should cut drains to the ponds in the low ground, and to assist in correcting the channel. The following is the estimate of the cost of this temporary work which would be utilized as a part of the permanent work if my project should meet the approval of the Commission.

ESTIMATE FOR TEMPORARY IMPROVEMENT AT LOWER OLD RIVER.

13,600 linear feet pile-dikes, at $3	$40,800
7,100 linear feet low mattress longitudinal dike, at $3	21,300
Menge dredge, with scows	10,000
One season's work with dredge	3,000
	75,100

"Of the work for the above outlay about one-half would be utilized in the plan for permanent improvement. The plant required for above work, in addition to the dredge, would be similar to that used in work on the Mississippi. Much to my disappointment, the surveys of the vicinity of mouth of Red River have not been completed, and I am obliged to present tracings from old maps, which, while not being correct in detail, are sufficiently so in general outline to give a fair understanding of the project presented.

"The exact location of dams or lines of channel is not attempted, and would require careful survey and study. Tracing-sheet No. 1 relates to the general plan; No. 2 to the temporary work in Lower Old River. The accompanying papers are two sheets (tracings showing channels) and seven sheets (cross sections), which are mailed in a separate package.

"Very respectfully, your obedient servant,

"AMOS STICKNEY,
"*Major of Engineers, U. S. A.*

"Lieut. Col. C. B. COMSTOCK,
"*Corps of Engineers, U. S. A.*,
"*President Mississippi River Commission.*"

In this project provision is made for keeping a navigable channel through Old River during the progress of the work. No definite action having been taken on this project, I was directed by the Commission to maintain the chanuel as heretofore by dredging. Having obtained the proper authority for the hire of a plant, two tugs and a stern-wheel steamboat started the work of scouring on August 8, 1884. At this time the depth of water was as follows:

On the bar at mouth of Old River, 13.5 feet. From mouth of Old River to the Atchafalaya the least depth was 13 feet on the crossing. On the bar at the head of the Atchafalaya River the least depth was 14 feet.

The tugs employed on the work were of sufficient draught and power to stir up the bottom long before the depth decreased to an extent to cause any interference to navigation. They worked until August 31, when the river had fallen to 9.4 feet at Red River Landing, and 6.8 feet at Barbre's Landing. It was then found that they could not cut away the bottom so as to maintain a channel deep enough for them to continue at work, and after some narrow escapes from capsizing, they were laid up at Barbre's Landing. A scraper was then made of anchors, and the lip of a dredge dipper fastened to a horizontal timber and hung over the bow of the stern-wheel steamer, which, backing down stream, dragged the scraper, and by this means gradually deepened the channel. But this was not sufficient to maintain a channel, as the material in suspension in the Mississippi River water was deposited in the comparatively broad channel between Chandler's and Barbre's. To confine the flow to a narrower channel, spurs were thrown out from the bar shore. They were constructed of willow brush, thrown between two rows of stakes, and weighted with sand-bags. Fifteen of these spurs, each about 60 feet long, were placed, and produced a good effect. Two of these willow structures were also placed on the bar at the mouth of Old River to define and help deepen the channel. A Menge dredge was employed to work in connection with the other boats. It was to have been at Old River about August 7, but owing to a breakage of her machinery, she did not arrive till August 26. This delay, however, was of little consequence, as the channel had been maintained with plenty of depth. It commenced work September 1, in the bar at the mouth, but owing to inability to hold itself in the current, accomplished little good. It was then taken to the bar at the head of the Atchafalaya, which had increased in width and shoaled considerably.

After working a short time it was removed to await new lines and anchor. On September 15 it was again placed at work on the bar at the mouth, and has been doing better but not entirely satisfactory work.

On September 12, the scraper having deepened the channel over the Atchafalaya bar to admit the tugs, they were put to work, and have maintained at least 7 feet depth. At last reports the depths through Old River were as follows:

From mouth to the gut, least depth, 7 feet; in the gut, least depth, 5 feet; from the gut to Chandler's Landing, least depth, 6 feet; Chandler's to Barbre's, least depth, 4 feet; on Atchafalaya bar, 7 feet.

This method of keeping Old River navigable during low water cannot be relied on. We have had a hard fight to maintain the channel, and I would recommend that some structures be placed for contracting the low-water channel before another season.

Approximate estimate of the cost of the work for the rectification of the mouth of the Red and Atchafalaya rivers, according to my project of December 15, 1883, with 10 per cent. added for contingencies, is $1,072,902.80.

The following is the report of Mr. A. O. Wilson on the survey of the vicinity:

"SURVEY OF THE MOUTH OF RED RIVER AND VICINITY.

"UNITED STATES ENGINEER OFFICE,
"*New Orleans, La., April 30, 1884.*

"MAJOR: I have the honor to submit the following report, with the map, cross-section sheets, and tables of gauge readings and current observations, made from the survey of the mouth of Red River and vicinity.

"In accordance with your instructions to proceed to the mouth of Red River and make a thorough and accurate survey of the vicinity, relocating and repeating all the cross-sections as shown on the maps from the surveys of 1879, 1880, and 1881, I arrived at the Red River Landing June 10, 1883, my party of twelve being complete, with the steam-launch Maud Rand, on the 22d of June.

"EXTENT AND METHOD OF SURVEY.

"The survey extends on the Mississippi River from a point below the Red River Landing to a point 2 miles above the mouth of Old River, consisting of a carefully chained traverse line up the right bank, with accurately located triangulating stations half a mile apart, from which a series of angles were taken upon flag stations placed along the opposite bank at every point or change in the line of the bank, and upon all prominent buildings, Government lights, and four triangulating stations along the left bank.

"The distance between the first two triangulating stations on the right bank is 2,235.86 feet, carefully measured and checked with a steel tape measure, constituted the base line of the triangulations, whereby all the other chained distances between stations have been checked and proved correct.

"The line of the top of the bank was taken by measured offsets every 200 feet from the transverse line. Sixteen cross-sections were taken in the Mississippi from Carr's Point to the Red River Landing; the locations of the soundings were made by angles measured by two transits on the stations, chosen so as to give an intersection on the range of the cross-section, each section being sounded over twice, the cross-sections being carried on to the top of the bank and connected with the traverse line by levels.

"A chained line, run with a transit and checked by stadia measure, was run from the swamp below the Red River Landing along the top of the levee to a point 5 miles below Simmsport, on the Atchafalaya River, with the topography, locating all churches, schools, gins, houses, roads, and fences in the vicinity of the river, also all the Atchafalaya cross-sections.

"A traverse line was run along the right bank of Old River from the Mississippi to the foot of Turnbull's Island, locating the cross-sections U, D, V, and H, with offsets every 200 feet, to the top of the bank, and angles on flag stations on the opposite bank; thence along Turnbull's Island, relocating the cross-sections of 1880 and 1881 in the Lower Old River, lettered, respectively, T, S, R, P, N, M, L, and K, where it is connected from Ash Cabin by triangulation with the line on the top of the levee near Chandler's Landing; also with the chained transit line, checked by stadia measure, running completely around Turnbull's Island, which locates all levee work, roads, and buildings on the island; also the 11 cross-sections taken in the Upper Old River, the cross-sections in the Red River, taken for the low-water discharge, and the cross-sections in Old River between the mouth of Red River and the head of the Atchafalaya River, previously taken in 1879, 1880, and 1881. A chained transit line was run from the foot of Turnbull's Island connecting with the Mississippi traverse line at Carr's Point.

"A chained transit line was run from the Mississippi at Carr's Point, locating the high ground and levee work, to the Upper Old River, connecting with the traverse line on Turnbull's Island at Cross-section No. III.

"The transit lines were connected with all the known fixed points of previous surveys, and permanently referred to 6 stone monuments, placed in pairs, one pair located on the high ground back from the Mississippi at Carr's Point, 1,376.05 feet apart; the second pair near the head of Turnbull's Island, 1,722.9 feet apart; the third pair on the side of the road between Chandler's Landing and Barbre's Landing, 1,611.1 feet apart, with Mississippi River Commission iron bench-mark in the plantation of J. Torras, and the stone monument bench-mark in the levee directly in front of the iron bench-mark, near the residence of J. Torras; also with the Coast and Geodetic Survey stone monument half a mile above the mouth of Old River, on the right bank of the Mississippi River.

"LINES OF LEVELS.

"Two lines of levels were run from the Red River Landing to Barbre's Landing, starting from a bench-mark established in 1880 by Mr. Rees; both lines agree with each other, and with the difference between the Red River Landing gauge and that at Barbre's Landing of 0.32, as established by Mr. Rees in 1880.

"A line of levels was carried down the Atchafalaya, checking with itself and with the bench-marks of Mr. Collins at Simmsport. A line of levels was carried from the mouth of Old River up the Lower Old River, and connecting with the line along the levee on every cross-section run from Turnbull's Island to the levee; another line ran completely around Turnbull's Island, showing the height and every break in the

levee work on the island, connecting and checking with a line of levels run from Barbre's Landing gauge to the discharge sections in Red River near the head of Turnbull's Island.

"A line of levels was run up the right bank of the Mississippi to a point 2 miles above the mouth of Old River; another line was run from the high ground at Carr's Point, showing the height and breaks of the levee work between the Mississippi and the Upper Old River, connecting with the level line on the island. A line was also run from Carr's Point across the bottom of the old bed of the Mississippi to the foot of Turnbull's Island. Bench-marks were established about every half mile on these lines, from which all the cross-sections were taken and the surface of the water at the time of sounding.

"NUMBER AND LOCATION OF CROSS-SECTIONS.

"The sixteen cross-sections in the Mississippi number from 0, at Carr's Point, to 15, at the Red River Landing; the numbers from 1 to 7 are in identically the same locations as sections previously taken in 1880 and 1881.

"*Cross-sections in Red, Old, and Lower Old rivers.*—Number 1, with another section sounded 200 feet below it, at the mouth of Red River, were taken on the 16th of October for the low-water discharge of Red River, the gauge at Barbre's Landing reading at the time —0.3 foot. At this time both the Upper and the Lower Old rivers were dry, so that the low-water discharge of Red River of 1883, amounting to 6,951 cubic feet per second, is exactly the same as the discharge through the head of the Atchafalaya River. The observations for the discharge were taken on a perfectly calm day by a series of floats run with sinkers at mid depths on each subdivision, the river being divided into ten subdivisions, and the discharge for each being calculated separately.

"Cross-sections 5, 7, 8, A, B, and C, in Old River, between the mouth of Red and the head of the Atchafalaya, are located as nearly as possible over the same lines as those similarly designated in the previous surveys. In the Lower Old River the cross-sections are lettered and located as those of the two previous surveys, and are as follows, commencing at Barbre's Landing: E, F, G, I, Z, X, K, L, M, N, P, R, S, and T, at the foot of Turnbull's Island; in the mouth of Old River, between Turnbull's Island and the Mississippi, Cross-sections D, V, and H, as located and sounded by Mr. John Ewens in 1882, and Section U of previous surveys.

"In the Atchafalaya the sections are distinguished by numbers. No. 2, at the head, down to No. 12, 2 miles above Simmsport, are over exactly the same line of section as those of Mr. Rees. Nos. 2, 4, 6, 8, 10, and 12 were taken; the others, Nos. 13, 14, 15, 16, and 17, though not exactly on the line, can be compared with sections previously taken close to them by Mr. H. C. Collins in 1880. The soundings for all the above-mentioned cross-sections were carefully located by angles measured with a transit, and calculated from a carefully measured base of not less than 500 feet, each section being sounded over three different times, each line being plotted and calculated separately from the others, so as to give a thorough check and detect any error.

"The cross-sections in the Upper Old River, with the exception of a part of two which were sounded as those in the Lower Old River, were taken by level and chain across the dry bed of the river; all cross-sections were connected with the traverse lines, both by transit and level. To facilitate any future comparison that may be required, the sections of the Upper Old River are numbered in Roman figures. No. VIII follows nearly the line of No III of the survey of 1879; No. VII, that of No. V; No. VI, of Nos. VII. Nos. V′, V, IV′, IV, III, II, and I are new sections. The map will show clearly the location and extent of the cross-sections; also the soundings taken and located by the intersection angles of two transits in the mouth of Old River and the Mississippi adjacent.

"OBSERVATIONS OF THE DIRECTION AND VELOCITY OF THE CURRENT IN THE MOUTH OF OLD RIVER.

"According to your letter of instruction received July 18, 1883, notes were taken every day of the direction of the current, and the velocity was ascertained by the running of two floats with sinkers suspended at average mid-depth. The course of the floats was about 50 feet on either side of the line of the deepest water in the channel, and the time taken while passing a carefully measured base line. The results of these observations are shown in the table of comparative gauge-readings, direction and velocity of the currents in the mouth of Old River.

"The actual readings of the Red River Landing gauge are reduced by 0.3 feet to the datum of the Barbre's Landing gauge, the zero of which is 0.3 feet above the zero of the Red River Landing gauge; and, by the following extract from Maj. W. H. H. Benyaurd's report to the Chief of Engineers, February 15, 1882, it is 3.06 feet above the level of Gulf. (Extract).

"The lowest water ever known at that point occurred on September 18, at which time the water service had fallen at Barbre's 1.20 feet below the zero of that gauge. This zero is 0.3 of a foot above the zero of the gauge at Red River Landing, which corresponds to the low water of 1872.

"From the date of the highest water of the year 1883, which occurred April 9, the direction of the current in Old River was out towards the Mississippi until July 1, when it changed in towards the Atchafalaya; during this time the fall of the water was slow and only amounted to 6.8 feet. The water was over the banks of Old River below the foot of Turnbull's Island until the end of July; the same condition of the direction and course of the current, as Mr. Rees notes in his report on the Survey of 1880, occurred frequently, namely, that at times when the difference of the water level of the Mississippi and the Red River was very slight, the current came down the Upper Old River from Red River to the foot of Turnbull's Island; thence, by the Lower Old River, into the Atchafalaya River. The annexed table of comparative gauge readings and notes of the direction of the current and its velocity will show that during the fall of the water the direction changed visibly five times, and that it was often almost stationary. The fall of the water was gradual until September 1, when the stage of the river was 14.90 at both gauges, after which the fall was rapid. October the 15th both the Upper and Lower Old rivers were dry.

"October 18, the water in the Mississippi having risen to 5.9 feet on the Red River Landing gauge, the flow of water in the Lower Old River resumed, the surface fall from the Mississippi to Barbre's Landing being 5.8 feet, and increasing to 6.9 feet on the 23d and 24th of October, the current at this time in the narrow gut near Ash Cabin being terrific. Both rivers steadily rose until December the 14th, the current, owing to the head of water more than to the surface fall, being very strong. The water fell on the Barbre's Landing gauge 9.4 feet from December 14 to December 30, the velocity of the current steadily decreasing, after which it suddenly increased in velocity and rose rapidly until the 15th of January, 1884, the strongest current being on the 9th and 10th of January, at the rate of 7.04 feet per second, or very nearly 5 miles per hour. January 23 the current was again almost imperceptible. At this date the current observations ceased, the survey being completed.

"OBSERVATIONS ON THE ATCHAFALAYA.

"The bottom and both banks of the Atchafalaya River are very ragged and irregular in their formation, caving and washing out in small, deep bays, the mouths of which are afterwards blocked up with sand-bars; large masses of earth frequently sliding into the bottom and standing up in sharp ridges or in rough pyramids, changing greatly the shape of a cross-section, and causing the current at high water to be very turbulent, full of whirlpools and vertical eddies.

"The table No. 2, showing the change in the areas above and below the datum line of the zero of Barbre's Landing gauge, with the amount of their scour or fill from 1880 to 1881, and 1881 to 1883, gives the information that the Atchafalaya continues to enlarge on every cross-section with two exceptions only, and those between the years of 1880 and 1881, the first on Cross Section No. 2 near the head, amounting to 1,550 square feet below the zero line; the other was on Cross-Section No. 6 and only amounted to 300 square feet. By examining the comparative cross-sections of that year in the Lower Old River this shoaling of the head of the Atchafalaya will be accounted for by the enormous scour shown on almost every cross-section, and the fact that there was a steady and strong current from the Mississippi towards the Atchafalaya during the fall from high to low water of 1881.

"The nature of the soil of which the bottom and banks is composed is of a very variable character, and in no portion within the limit of the survey can a cross-section be obtained that will show the same character of soil from bank to bank. A notable subsidence is shown on the comparative Cross-Section No. 6, where a very large mass of bank, apparently of a stable character, settled vertically, leaving a perpendicular break in the bank of 13 feet in height. This took place between the months of June and November, 1883.

"The flood surface slope at the highest stage of the Atchafalaya ever known on the first 32 miles from the head had an average slope of 6¼ inches to the mile, taken from the high-water mark at Barbre's Landing of the year 1882, which was found by Mr. H. W. W. Reynolds to be 50.21 feet above the zero of the gauge, and the high-water mark at West Melville, the point 32 miles from the head, where the New Orleans Pacific Railroad crosses, the elevation of which, referring to the same datum, is 34 feet, and would read 37 feet on the West Melville gauge as it now stands.

"I will here add the flood notes of 1884, as they may be of interest.

"By the different gauge readings the highest water at the Red River Landing, Barbre's Landing, and Simmsport (5 miles from the head of the Atchafalaya) gauges, was recorded March 30 and 31, 1884, and was as follows, respectively, referring to the datum of the zero of Barbre's gauge, 47, 48.60, and 46.55 feet, and the West Melville

gauge reading the same date March 31, 30.45 feet, and arriving at the highest point April 5, 30.8 feet. From the above data we find the flood surface fall on March 31, 1884, on the first 32 miles, to be at the average rate of 6¾ inches to the mile, and on the first 5 miles, 5 inches to the mile.

"The low-water surface slope of the Atchafalaya on the first 32 miles from the head, from the gauge readings October 16, 1883, was found to be five-eighths of an inch to the mile, and the discharge through the head 6,951 cubic feet per second, Barbre's gauge reading 0.3 below zero, and the West Melville, referring to the same 2.1 feet below, which was the lowest of the year, and Barbre's the next day, October 17, 1883, 0.4 foot below, at which time there was not the slightest discharge either from the Upper or Lower Old rivers, and the water very clear and free from sediment.

"OBSERVATIONS IN THE LOWER OLD RIVER.

"It is well known that what is now called Old River once formed the bed of the Mississippi River, now very much filled up by river deposit of a mixed and very unstable class of soil. In the Lower Old River, when the current is out towards the Mississippi, the bar on the north side builds rapidly. The growth of young willows opposite Barbre's Landing forms a natural screen through which the current runs, causing it to deposit its sediment along the bar which extends to the crossing near Cross-Section X, where it joins or overlaps the bar formed in a like manner along the south side of this part of the river by the current when it is 'in' from the Mississippi River.

"It is plain to the observer, and proved by a series of surveys, that as the direction of the current is subjected to change, either 'in' or 'out,' with a large natural screen to check the velocity and thereby precipitate the sediment carried by the flood waters, the condition of the low-water channel must continue to get worse. It is true that some years the low-water channel may improve temporarily. This is brought about, as in the year 1881, by the current continuing in one direction for an unusual length of time, and as this is more liable to be 'in' from the Mississippi owing to the closure of the Tensas by levees so that there is a possibility of the channel from the Mississippi through the Lower Old River being improved, but not without also increasing the enlargement of the Atchafalaya. The table showing the comparative scours and fills, and the cross-sections will show the enormous scour that took place during the year 1881, and the table of gauge readings with the direction and velocity of the current through the mouth of Old River account for it; the same tables also show and account for the very large amount of deposit shown from the year 1881 to 1883, and proves the eccentricity that the locality is liable to. The report of Major Benyaurd to the Chief of Engineers of 1882 mentions the possibility of a condition of the low-water channel which actually occurred this season of 1883—very sluggish currents with the constant changes of direction shown in the year 1880, which, together with the rapid fall of both rivers after September 1, and the low stage that the water fell to on the Red River Landing and Barbre's Landing gauges, made it impossible to keep navigation open by the method of previous years; namely, the dredge at the mouth of Old River, and two propeller tugs, with a stern-wheel steamer.

"All navigation through the Old River was stopped from September 27 to October 18. The sloughing and sliding in of the banks, remarked in previous low-water seasons, took place, to a very large extent, along both banks of the low-water channel of the Lower Old River, from the Crossing to the Mississippi. This is caused by the sustaining pressure of the water being removed, the suction power of the water oozing out through the sandy strata in the deposited soil with which the banks are formed. Where the sloughing of the bank is only slight, the water with which the banks are saturated has been enough to affect them; but, in every case where the sloughing has been extensive, land-locked water has been found in ponds or sloughs at some little distance behind the slides. The sliding in of both banks in what is called the Gut, near Ash Cabin, pushed the soft mud of the bottom up into two mud walls, with a channel only 22 feet wide between them. These walls being exposed to the air soon became hard enough to walk upon; in the portion of the Channel from Ash Cabin to the crossing, flat-topped circular, mud lumps were forced up by water and gas jets, leaving them in the shape of an inverted soup plate, with a small, deep, round hole in the center. A very large subsidence on the right bank in the mouth of Old River took place August 28, 1883; it extended fully 2,000 feet along the bank, and its cross-section area is shown on Cross-Section V; in this locality the deposit on the top of the bank by levels taken February, 1883, and August 26 of the same year, amounted to 2 feet, divided into two distinct classes, the lower half being of pure sand and the upper of a soft, brown clay substance. The mud bars, or low-water banks, show by the cross-sections a large deposit all through the Lower Old River since 1881. The bar from Barbre's Landing to the crossing is formed chiefly of red sand similar to the banks of Red River; very little of this is seen in the bars between the crossing and the Mississippi River.

"OBSERVATIONS IN THE MISSISSIPPI RIVER IN THE VICINITY OF THE MOUTH OF OLD RIVER.

"The accompanying map of the Mississippi River from Carr's Point to the Red River Landing shows the location of the cross-sections, the contour lines of 1884, and the change in the line of the right bank above the mouth of Old River.

"In this portion of the river the comparative cross-sections show that the channel near the right bank is deepening greatly and the bank is steadily washing. In many places it is now almost perpendicular, though only one cave of any extent is noticeable below Carr's Point; the channel on the opposite side is shoaling up and the bank is making on the low-water portion.

"The cross-sections Nos. 1 to 7, inclusive, are a repetition of those of 1880 and 1881; Nos. 8, 9, 10, 11, 12, 13, 14, and 15 are new lines, but comparative cross-sections have been made from the soundings, on the lines of the three cross-sections taken below the mouth of Old River in 1881, No. 1 of which shows the right bank to be extending out; but with this exception and the shoaling of the deep channel near the left bank the cross-sections show considerable enlargement and a large scour on the Angola Bar. The comparisons may be affected by the different stages of the river at the time the soundings were taken, those of 1880 and 1881 being taken at less than 9 feet on the gauge, and those of this survey in January, 1884, with over 32 feet on the gauge and a strong current running. The contour lines show that a good, navigable channel of 20 feet below extreme low water exists both above and below the mouth of Old River as the survey extends either way.

"The location of the three cross-sections of 1881 below the mouth of Old River are shown by dotted lines on the map of the Mississippi, plotted on the scale of 200 feet to 1 inch.

"OBSERVATIONS IN THE UPPER OLD RIVER.

"The cross-sections in the Upper Old River show the bottom of the river in the channel to be 7.5 feet above zero on cross-section No. 11, and on the other sections from 4 to 6 feet above; the character of the bottom being soft mud, the banks as compared with the Lower Old River are much more stable and free from sloughing, and, with the exception of the entrance through the Sugar-House Chute, the river presents a much more navigable appearance and is favored by steamboatmen whenever there is water enough to go through it.

"The Upper Old River for its entire length may be said to have one old and reliable bank free from sloughing, though it is not always on the same side, and the opposite bank is more systematically contracted by the natural-growth willows than the Lower Old River; a very slight amount of work would concentrate and confine the low-water channel, and if by any means the current was so controlled, so as to cause it always to flow in one direction, the channel would quickly scour out and maintain itself.

"The survey was prosecuted under very great difficulties, the character of the malarial fevers peculiar to the locality being more virulent than the residents have known for years; of the party that I commenced with not one was able to remain through the survey with me; during the survey I had four different levelers, eight different rodmen, six cooks, and the changes among the boat and axmen were incessant; two of my party died soon after leaving the work, and several were ill for months afterwards, the amount of time lost by sickness being nearly equal to the actual time consumed while at work on the survey; this will account for the somewhat slow progress made on a survey at any time very tedious to make, on account of the difficulty in finding the exact location of the cross-sections previously taken, so as to insure a fair comparison.

"Accompanying this report are:

"Table No. 1. Showing the gauge-readings from the date of the highest water of 1883 to the end of January, 1884, with the direction and velocity of the current through Old River during the time of the survey.

"Table No. 2. Showing the changes in the areas of the Atchafalaya cross-sections above and below the zero line of Barbres Landing gauge, which is approximately low water.

"Table No. 3. Showing the changes in the depths on the line of deep water in the low-water channel through Old and Lower Old River to the Mississippi River. A large map of the whole survey plotted on a scale of 800 feet to 1 inch.

"A map of the Mississippi River in the vicinity of the mouth of Old River, plotted on a scale of 200 feet to 1 inch.

"No. 1. Roll of cross-sections in the Atchafalaya River.

"No. 2. Roll of cross-sections in the Upper Old River.

"No. 3. Roll of cross-sections in the Old and Lower Old River.

"No. 4. Roll of cross-sections in the Mississippi River, 1884.

"No. 5. Cross-sections in the Mississippi below the mouth of Old River, 1881, compared with soundings of 1884.

"I have endeavored to divide up and arrange this report under different headings in order to facilitate comparison with the previous surveys and reports, and to save time in referring to different parts."

TABLE No. 1.—*Gauge-readings at Red River Landing, Barbre's Landing, and mouth of Old River, Louisiana, with directions and velocity of current through Old River, and rise and fall between Red River Landing and Barbre's Landing, referring to the zero of Barbre's Landing.*

Date.		Red River Landing.	Barbre's Landing.	Difference.	Old River, near the mouth. Direction of current.	Velocity of current per second.	Gauge.	Remarks.
1883.						Feet.		
Apr.	9	44.90	46.30	1.40	Out*			High water of 1883.
	10	44.85	[illegible]	1.45	Out			
	11	44.75	46.20	1.45	Out			
	12	44.65	46.10	1.45	Out			
	13	44.53	46.00	1.47	Out			
	14	44.42	45.80	1.38	Out			
	15	44.30	[illegible]	1.30	Out			
	16	44.15	45.50	1.35	Out			
	17	44.00	45.30	1.30	Out			
	18	43.85	45.10	1.25	Out			
	19	43.70	44.90	1.20	Out			
	20	43.57	44.80	1.23	Out			
	21	43.45	[illegible]	1.15	Out			
	22	43.33	[illegible]	1.07	Out			
	23	43.33	44.40	1.07	Out			
	24	43.21	44.20	0.99	Out			
	25	43.11	44.10	0.99	Out			
	26	42.95	[illegible]	0.95	Out			
	27	42.80	43.80	1.00	Out			
	28	42.73	43.90	1.17	Out			
	29	42.73	43.90	1.17	Out			
	30	42.64	43.60	0.96	Out			
May	1	42.58	43.50	0.92	Out			
	2	[illegible]	43.40	0.92	Out			
	3	42.40	43.30	0.90	Out			
	4	42.35	43.20	0.85	Out			
	5	42.37	[illegible]	0.93	Out			
	6	42.37	43.30	0.93	Out			
	7	42.20	43.10	0.90	Out			
	8	42.15	43.00	0.85	Out			
	9	[illegible]	43.00	0.80	Out			
	10	42.20	43.10	0.90	Out			
	11	42.20	43.10	0.90	Out			
	12	42.17	43.10	0.93	Out			
	13	42.14	43.10	0.96	Out			
	14	42.10	43.10	1.00	Out			
	15	42.10	43.10	1.00	Out			
	16	42.10	43.00	0.90	Out			
	17	42.08	43.00	0.92	Out			
	18	42.05	43.00	0.95	Out			
	19	42.00	42.90	[illegible]	Out			
	20	41.95	42.80	[illegible]	Out			
	21	41.90	42.80	0.90	Out			
	22	41.80	42.60	0.80	Out			
	23	41.60	42.40	0.80	Out			
	24	41.40	42.20	0.80	Out			
	25	41.15	42.20	1.05	Out			
	26	41.10	42.10	1.00	Out			
	27	40.80	42.00	1.20	Out			
	28	40.60	41.80	1.20	Out			
	29	40.45	41.50	1.05	Out			
	30	40.37	41.40	1.03	Out			
	31	40.50	41.40	0.90	Out			
June	1	[illegible]	41.20	0.90	Out			
	2	40.20	41.00	0.80	Out			
	3	40.20	41.00	0.80	Out			
	4	40.15	40.90	0.75	Out			
	5	40.00	40.70	0.70	Out			
	6	39.90	40.60	0.70	Out			

* "Out" means towards the Mississippi River.

TABLE No. 1.—*Gauge-readings at Red River Landing, &c.*—Continued.

Date.		Red River Landing.	Barbre's Landing.	Difference.	Old River, near the mouth. Direction of current.	Velocity of current per second.	Gauge.	Remarks.
1883.						Feet.		
June	7	39.80	40.40	0.60	Out	....	....	
	8	39.70	40.30	0.60	Out	....	....	
	9	39.55	40.10	0.55	Out	....	....	
	10	39.45	40.00	0.55	Out	....	....	Current three miles per hour.
	11	39.35	39.80	0.45	Out	....	....	
	12	39.25	39.80	0.55	Out	....	....	
	13	39.20	39.70	0.50	Out	....	....	
	14	39.20	49.70	0.50	Out	....	....	
	15	39.05	39.60	0.55	Out	....	....	
	16	38.90	39.50	0.60	Out	....	....	
	17	38.80	39.30	0.50	Out	....	....	
	18	38.70	39.20	0.50	Out	....	....	
	19	38.60	39.10	0.50	Out	....	....	
	20	38.50	39.00	0.50	Out	....	....	Three miles per hour.
	21	38.40	39.00	0.60	Out	....	....	
	22	38.30	39.00	0.70	Out	....	....	
	23	38.30	38.90	0.60	Out	....	....	
	24	38.25	38.90	0.65	Out	....	....	
	25	38.20	38.80	0.60	Out	....	....	
	26	38.20	38.80	0.60	Out	....	....	
	27	38.15	38.70	0.55	Out	....	....	
	28	38.15	38.70	0.55	Out	....	....	
	29	38.15	38.70	0.55	Out	....	....	
	30	38.15	38.70	0.55	Out	....	....	
July	1	38.10	38.00	0.10	In*	....	....	Changes towards the Atchafalaya River.
	2	38.05	38.00	0.05	In	....	....	
	3	38.03	38.00	0.03	In	....	....	
	4	38.01	37.90	0.11	In	....	....	Current very slight.
	5	38.00	37.90	0.10	In	....	....	Do.
	6	38.05	38.00	0.05	In	....	....	Do.
	7	38.05	38.00	0.05	In	....	....	Do.
	8	38.10	38.00	0.10	In	....	....	Do.
	9	38.10	38.00	0.10	In	....	....	Do.
	10	38.15	38.00	0.15	In	....	....	
	11	38.25	38.10	0.15	In	....	....	
	12	38.25	38.10	0.15	In	....	....	
	13	38.25	38.00	0.25	In	....	....	
	14	38.20	38.00	0.20	In	....	....	
	15	38.15	38.00	0.15	In	....	....	
	16	38.10	38.00	0.10	In	....	....	
	17	38.00	38.00	0.00	In	....	....	Current changing.
	18	37.90	37.90	0.00	In	....	....	Current imperceptible.
July	19	37.70	37.50	0.20	In	....	....	Current imperceptible.
	20	37.45	37.20	0.25	In	....	....	Current very slight.
	21	37.20	37.00	0.20	In	....	....	Do.
	22	36.80	36.70	0.10	In	....	....	
	23	36.40	36.50	0.10	Out	1.307	36.50	Changes.
	24	36.00	36.10	0.10	Out	....	36.00	Strong wind; current very slight.
	25	35.70	36.10	0.40	Out	1.294	35.77	
	26	35.45	35.60	0.15	Out	1.358	35.55	
	27	35.25	35.40	0.15	Out	1.232	35.30	
	28	....	35.10	....	....	....	....	
	29	34.80	34.90	0.10	Out	1.272	34.80	
	50	34.50	34.50	0.00	Out	0.987	34.50	Very slow.
	31	34.10	34.20	0.10	Out	1.149	34.10	Do
Aug.	1	33.70	34.30	0.60	Out	1.713	33.70	
	2	33.40	33.70	0.30	Out	1.862	....	
	3	33.10	33.00	0.10	Out	1.917	33.30	
	4	31.90	32.10	0.20	Out	2.342	....	
	5	....	31.10	....	....	....	....	
	6	29.50	30.60	1.10	Out	2.500	....	
	7	28.40	29.90	1.50	Out	2.863	....	
	8	27.30	28.50	1.20	Out	2.708	....	
	9	26.30	27.90	1.60	Out	2.342	26.50	
	10	25.40	26.90	1.50	Out	2.043	25.65	
	11	24.70	25.10	0.40	Out	1.413	25.00	
	12	....	24.50	....	....	....	....	
	13	23.75	24.00	0.25	....	....	24.10	Almost imperceptible.
	14	23.45	23.60	0.15	Out	....	23.75	Almost imperceptible.
	15	23.15	23.30	0.15	In	....	23.40	Do.

* "In" means towards the Atchafalaya River.

TABLE No. 1.—*Gauge-readings at Red River Landing, &c.*—Continued.

Date.	Red River Landing.	Barbre's Landing.	Difference.	Old River, near the mouth. Direction of current.	Velocity of current per second.	Gauge.	Remarks.
1883.					*Feet.*		
Aug. 16	22.80	23.00	0.20		....	23.10	Current imperceptible.
17	22.50	22.80	0.30		0.197	22.80	Do.
18	22.20	22.50	0.30		....	22.40	Strong wind
19		22.10			....		
20	21.30	21.80	0.50		....	21.50	Gale SW.
21	20.75	20.50	0.25	In	1.216	21.10	Current changes.
22	20.20	19.30	0.90	In	1.281	20.40	
23	19.50	19.00	0.40	Out	1.300	19.70	Do.
24	18.80	19.40	0.60	Out	1.055	19.05	
25	18.20	18.40	0.20	Imperceptible.		18.35	Wind high; north.
26		17.40			....	....	Sunday.
27	16.90	16.40	0.50	In	0.967	17.05	
28	16.30	16.10	0.20	In	1.042	16.45	
29	15.60	15.20	0.40	In	1.200	15.85	
30	14.95	14.50	0.45	In	1.126	15.15	
31	14.35	14.00	0.35	In	1.227	14.50	
Sept. 1	13.90	13.90	0.00	In	1.312	13.90	
2	....	13.20	....		....	....	
3	12.95	12.60	0.35	In	1.255	12.85	
4	12.45	12.10	0.35	In	1.257	12.40	
5	12.00	11.40	0.60	In	1.320	12.00	
6	11.50	11.20	0.30	In	1.100	11.60	
7	11.00	10.50	0.50	In	1.186	11.00	
8	10.50	10.10	0.40	In	1.236	10.55	
9	....	9.30		....	....	....	
10	9.45	8.60	0.75	In	1.031	9.45	
11	8.95	8.00	0.95	In	0.987	9.00	
12	8.55	7.50	1.05	In	1.000	8.55	
13	8.10	7.00	1.10	In	1.060	8.15	
14	7.85	6.50	1.35	In	1.135	7.80	
15	7.60	6.00	1.60	In	1.094	7.60	
16	7.50	5.30	2.20	In	....	7.60	
17	7.70	5.30	2.40	In	1.218	7.65	
18	7.20	5.00	2.20	In	0.933	7.10	
19	6.70	4.50	2.20	In	1.107	6.55	
20	6.25	4.00	2.25	In	1.086	6.17	
21	6.05	3.80	2.25	In	0.890	5.96	
22	5.80	3.30	2.50	In	0.644	5.70	
23	5.55	2.80	2.70	In		....	
24	5.40	2.50	2.90	In	0.326	5.26	
25	5.20	2.30	2.90	In	0.391	5.15	
26	4.90	2.10	2.80	In	0.256	4.86	
27	4.65	1.90	2.75	In	0.810	4.64	
28	4.50	1.50	3.00	In	0.925	4.40	
29	4.40	1.30	3.10	In	0.406	4.30	
30	4.30	1.20	3.10	In	....	....	
Oct 1	4.20	1.10	3.10	In	0.391	4.20	
2	4.15	1.10	3.05	In	0.281	4.15	
3	4.10	1.00	3.10	In	0.301	4.10	
4	3.95	0.90	3.05	In	0.236	3.95	
5	3.80	0.60	3.00	No flow.	0.000	3.90	Old River is dry.
6	3.70	0.70	3.00	No flow.	0.000	3.80	Do.
7	3.65	0.40	3.25	No flow.	....	....	
8	3.65	0.20	3.45	No flow.	0.000	3.70	Lowest reading of Red River Landing gauge 1883.
9	3.80	0.00	3.80	No flow.	0.000	3.85	Zero, Barbre's gauge.
10	4.00	0.20	4.20	No flow	0.000	4.08	No flow in Old River.
11	4.10	0.10	4.20	No flow	0.000	4.14	Do.
12	4.20	0.00	4.20	No flow.	0.000	4.25	Do.
13	4.30	0.00	4.30	No flow	0.000	4.35	Do.
14	....	0.00	....	No flow	....	....	Do.
15	4.35	0.20	4.70	No flow.	0.000	4.60	Do.
16	4.80	0.30	5.10	No flow.	0.000	4.75	Do.
17	5.05	0.40	5.45	No flow.	0.000	5.20	Lowest water of 1883 on Barbre's gage.
18	5.60	0.20	5.80	No flow.	0.000	5.75	Commencement of flow in Lower Old River.
19	5.90	0.10	5.80	In	0.574	6.10	
20	6.30	0.40	5.90	In	....	6.60	Stormy.
21	6.80	0.70	6.10	In	....	6.80	Do.

TABLE No. 1.—*Gauge-readings at Red River Landing, &c.*—Continued.

Date.	Red River Landing.	Barbre's Landing.	Difference.	Old River, near the mouth.			Remarks.
				Direction of current.	Velocity of current per second.	Gauge.	
1883.					*Feet.*		
Oct. 22	7.70	1.00	6.70	In	....	7.70	
23	8.10	1.20	6.90	In	....	8.10	Stormy.
24	8.45	1.50	6.90	In	1.213	8.50	
25	8.75	2.00	6.75	In	1.320	8.75	Strong north wind.
29	9.05	2.50	6.55	In	1.173	9.05	
27	9.50	3.70	5.80	In	0.996	9.50	
28	....	5.00	......	In		....	
29	10.35	6.50	3.85	In	....	10.40	Stormy.
30	10.65	7.10	3.55	In	1.760	10.75	
31	10.95	8.10	2.85	In	1.821	11.00	
Nov. 1	....	8.80	......	....	....	....	Dense fog.
2	11.05	9.20	1.85	In	1.885	11.10	
3	10.90	9.20	1.80	In	1.760	10.90	
4	....	9.20	......	In		....	
5	10.60	9.20	1.40	In	1.731	10.65	
6	10.65	9.30	1.35	In	....	10.70	North wind.
7	10.90	9.40	1.50	In	1.676	10.95	
8	11.45	9.70	1.75	In	2.247	11.70	
9	12.35	10.30	2.05	In	2.640	12.45	Rapid rise.
10	13.60	11.00	2.60	In	....	13.90	Stormy weather.
11	15.60	13.10	2.50	In		....	
12	17.35	15.40	1.95	In	3.249	17.50	
13	17.80	17.00	0.45	In	3.060	17.80	
14	18.20	17.80	0.40	In	2.400	18.15	
15	18.40	18.10	0.30	In	2.011	18.40	
16	18.55	18.30	0.25	In	2.030	18.55	
17	18.70	18.50	0.20	In	1.650	18.70	
18	19.00	18.70	0.30	In	....	19.15	
19	19.30	18.90	0.40	In	1.760	19.30	
20	19.70	19.50	0.20	In	2.112	19.70	
21	21.05	20.60	0.55	Out	2.640	20.05	Current changes.
22	20.45	21.40	0.95	Out		....	Stormy weather.
23	22.00	22.30	0.30	Out	0.880	22.10	
24	22.40	22.60	0.20	Out	0.335	22.57	
25	22.50	22.70	0.20	Out		....	
26	22.55	22.80	0.25	Out	....	22.70	
27	22.45	22.70	0.25	Out	....	22.50	Almost imperceptible.
28	22.05	22.30	0.25	....	....	22.10	Point of observation changes to near Barbre's Landing.
29	21.80	22.10	0.30	Out	0.498	....	
30	21.80	22.00	0.20	Out	0.586	22.00	
Dec. 1	22.05	22.20	0.15	In	1.056	....	Current changes.
2	22.60	22.70	0.10	In	1.354	....	
3	23.45	23.30	0.15	In	1.959	....	
4	24.25	24.00	0.25	In	2.446	....	Current very strong at mouth of Old River.
5	25.15	24.80	0.35	In	3.106	....	
6	25.80	25.30	0.50	In	3.520	....	
7	26.30	25.70	0.50	In	3.300	26.48	
8	26.85	26.30	0.50	In	2.640	....	
9	27.20	26.70	0.50	In	2.708	....	
10	27.40	26.90	0.50	In	2.779	....	
11	27.25	27.00	0.25	In	2.933	....	
12	27.30	27.00	0.30	In	2.933	....	
13	27.30	27.00	0.30	In	2.351	27.45	
14	27.40	27.10	0.30	In	2.843	....	
15	27.30	27.10	0.20	In	2.640	....	
16	27.10	26.90	0.20	In	1.992	....	
17	26.70	26.60	0.10	In	2.400	....	
18	26.25	26.20	0.05	In	1.885	....	
19	25.50	25.60	0.10	Out	1.703	....	Current changes.
20	24.60	24.90	0.30	Out	1.576	....	
21	23.90	24.20	0.35	....	1.371	24.12	
22	23.00	22.90	0.10	In	1.242	....	
23	22.25	22.70	0.45	....	....	....	Sunday. Point of observation changed back to mouth of Old River.
24	(*)	21.90	......	In	1.193	21.97	
25	(*)	21.20	......	....	....	....	
26	(*)	19.60	......	In	0.165	20.90	

* No gauge.

TABLE No. 1.—*Gauge-readings at Red River Landing, &c.*—Continued.

Date.	Red River Landing.	Barbre's Landing.	Difference.	Old River, near Barbre's Landing. Direction of current.	Velocity of current per second.	Gauge.	Remarks.
1883.					*Feet.*		
Dec. 27	(*)	19.00	......	In........	[redacted]	20.29	
28	(*)	18.60	.....	In	0.165	19.90	
29	(*)	18.30	....	In	0.165	19.65	
30	(*)	18.70			....	....	
31	21.85	22.20	0.35	Out	1.652	22.19	Stormy.
1884.							
Jan. 1	23.10	23.50	0.40	Out	3.017	23.18	
2	24.25	24.50	0.25	Out	1.553	24.30	
3	25.75	25.90	0.15	Out	0.000	25.85	Current changing.
4	27.30	27.30	0.00	In	2.355	27.35	Strong current.
5	29.05	28.70	0.35	In .. .	2.355	29.20	Do.
6	30.10	29.80	0.30	In........	....	....	Strong current, stormy.
7	31.05	30.70	0.35	In .. .		....	Do.
8	31.90	31.60	0.30	In..... .	4.224	32.00	Very strong current.
9	32.55	32.30	0.25	In.......	7.040	32.40	Do.
10	33.10	32.80	0.30	In.......	7.040	33.30	Do.
11	33.55	33.20	0.35	In.... ...	5.867	33.85	Do.
12	33.75	33.40	0.35	In .. .	5.280	33.78	
13	33.90	33.60	0.30	In		....	
14	33.95	33.70	0.35	In.. ..	4.600	33.88	
15	34.00	33.80	0.20	In	4.224	34.03	
16	33.65	33.80	0.25	In . .	3.911	33.99	
17	33.70	33.80	0.10	In.......	3.520	33.89	
18	33.75	33.80	0.05	In ..	3.200	33.99	
19	33.75	33.90	0.15	In .. .	3.017	34.00	
20	33.45	33.60	0.15	In......	....	....	
21	33.00	33.30	0.30	In.... ...	1.624	33.39	
22	32.55	32.90	0.35	In	1.056	32.99	
23	32.10	32.50	0.40	In	....	[redacted]	Strong south wind; current imperceptible.
24	32.20	32.50	0.30	....	....	....	Current changing.
25	32.00	32.40	0.40	....	....	....	Current observations ceased.
26	31.85	32.30	0.45	....	....	....	
27	31.80	32.20	0.40	....	....	....	Departure for Black Hawk.
28	31.85	32.20	0.35	....	....	....	
29	31.95	32.20	0.25	....	....	....	
30	32.00	32.30	0.30	....	....	....	
31	32.05	32.40	0.35	....	....	....	

* No gauge.

TABLE No. 2.—*Showing areas and changes in area above and below zero of Barbre's Landing gauge, and greatest depths sounded by W. M. Rees in* 1880, *H. St. L. Coppée in* 1881, *and A. Owen Wilson in* 1883.

ATCHAFALAYA RIVER.

Sections.	Areas above and below zero of Barbre's Landing gauge. 1880. Above.	1880. Below.	1881. Above.	1881. Below.	1883. Above.	1883. Below.	Changes from 1880 to 1881. Above zero scour.	Below zero. Fill.	Below zero. Scour.	Changes from 1881 to 1883. Above zero scour.	Below zero scour.	Greatest depths below zero of Barbre's Landing gauge. [redacted]	[redacted]	1883.
No. 2	49,360	31,930	50,100	30,380	57,780	40,020	740	1,550	..	7,680	9,640	66.7	60.7	78.5
No. 4	32,320	6,300	33,220	6,780	34,800	8,180	900	....	480	1,580	1,400	35.3	40.0	35.5
No. 6	33,120	8,400	33,660	8,100	35,620	11,420	540	300	.	1,960	3,320	27.1	26.8	30.7
No. 8	31,240	7,920	31,700	8,360	33,240	14,660	460	..	440	1,540	6,300	38.2	37.5	54.6
No. 10	37,640	11,100	38,260	11,860	38,960	15,220	620	....	760	700	3,360	29.7	32.6	40.7
No. 12	38,500	11,160	38,860	11,660	44,100	14,520	360	....	500	5,240	2,860	39.6	40.6	37.6

TABLE No. 3.—*Showing scour or fill on the line of the deepest water in the channel through Old and Lower Old rivers, according to the surveys of* 1880, 1881, *and* 1883.

Cross-section.	1880 to 1881.		1881 to 1883.		1880 to 1883.	
	Scour.	Fill.	Scour.	Fill.	Scour.	Fill.
A		1.5	2.0		0.5	
B		1.5		1.0		2.5
C	0.5			3.5		3.0
E	1.0			4.0		3.0
F	6.0			2.0	4.0	
G	10.0			7.0	3.0	
I	10.0			8.5	1.5	
Z	4.5			14.0		9.5
X	5.0			1.0	4.0	
K	8.0			5.5	2.5	
L	4.0			6.0		2.0
M	0.2			5.5		5.3
N	8.5			5.8		2.3
P	8.0			6.0	2.0	
R	7.0			5.5	1.5	
S	8.0			3.0	5.0	
T	8.5			4.0	4.5	
V	5.0			4.0	1.0	
U		18.0		1.0		19.0

"I am, very respectfully, your obedient servant,

"ARTHUR OWEN WILSON,
"*Assistant Engineer.*

"Maj. AMOS STICKNEY,
"*Corps of Engineers, U. S. A., New Orleans, La.*"

MONEY STATEMENT.

In Treasury Department, Washington, September 30, 1882		$75,000 00
Transfer September 30, 1882		8,153 94
Allotment July 19, 1884		12,290 00
Drawn	$83,571 26	
Transfer and deposit	571 26	
		83,000 00
Not drawn		4,290 00
On hand, assistant treasurer, New Orleans, La., September 30, 1884		17,821 42
In hands of assistants		388 00
Expended since September 30, 1882		72,944 52
Balance due from appropriation October 31, 1883		14,729 52
Received since October 31, 1883		61,571 26
Expended since October 31, 1883		28,632 32
Balance on hand September 30, 1884		18,209 42
Total appropriated	$190,000 00	
Allotment July 19, 1884	12,290 00	
		202,290 00
Total expended		179,790 55

IMPROVING HARBOR AT NEW ORLEANS, LOUISIANA.

At the time of last annual report work was in progress in Carrollton Bend. The work contemplated was the protection of the sloping river bank from low-water mark to the bottom of the river by means of a continuous mattress of brush and stone. To accomplish this it was intended to make the mattress in one piece 400 feet wide and about 10,000 feet long. Owing to unavoidable delay caused by the delinquency of contractors in furnishing material and a rise in the river, the weaving of mattress had to be suspended when a length of only 470 feet had been constructed. This was successfully sunk, but on account of insufficiency of ballast and a changing of the current a small portion of it came up and was lost. It was demonstrated, however, that a wide mattress could be placed in deep water when there was not a strong current. On the resumption of work, after the subsiding of the river, the location and method of protection were changed, the change of method being to suit the new locality where wharves render it impracticable to construct and maintain a mattress covering. The following is the project for the work:

"UNITED STATES ENGINEER OFFICE,
"*New Orleans, La., April 22*, 1884.

"SIR: In compliance with the resolution of the Commission of November 20, 1883, I have the honor to submit herewith a report of my assistant, Mr. W. G. Price, upon the relative importance of protecting the Gouldsborough Bend, in the harbor of New Orleans, as compared with other work contemplated in the project approved by the Commission. There is, I think, no question of the greater immediate importance of protecting Gouldsborough Bend, which is rapidly increasing. I believe that work should be commenced for preventing the caving of the banks at once, and have had a plan and estimates prepared by Mr. Price, assistant engineer, which, with the accompanying maps, is also presented herewith, as well as plan, maps, &c., for protecting the Gretna Bend, which is just above the Gouldsborough Bend, one being almost a continuation of the other. Owing to the difficulty of placing continuous mattress work on the banks on account of the standing and wrecked wharves, and the belief that mattress work would be destroyed by the collection of heavy deposits of sediment at all points where wharves were placed, I have had plans prepared for the protection of the bank by means of submerged spurs of brush and stone placed so as to throw the contour lines of the bank about 50 feet out into the river. I would propose to locate these spurs at the salient points of the deep-water lines. Experience in the first reach protected would in the first season show whether the spurs were properly placed, and if a greater number were needed to thoroughly protect the bank they could be added afterwards. The plans are based upon the survey of 1877–'78 and are intended to show in a general way the method of constructing and placing the spurs. A new survey will be made as soon as the stage of water will permit, from which to determine the exact locations.

"The entire length of bank from opposite a point just above the City Park down to Algiers, as shown on accompanying map, will eventually need protection, but the greatest immediate need is in the lower bend in the front of Gretna and Gouldsborough, and more particularly in front of Gouldsborough where the caving is worse, and commercial interests greatest.

"The estimate for the Gouldsborough part is $64,200, and for the Gretna part $64,200, exclusive of plant. The plant required is about as follows:

6 barges, at $3,000 each	$18,000
To build mattress-ways on three of them	1,500
Ways built on the bank for constructing crib for spur	300
1 stern-wheel steamboat	15,000
Capstans, rope, and tools	3,000
Making a total of	37,800

"In making provision for this work I am of the opinion that the Carrollton work should not be suspended. The plant for that work is all ready. The method of working has been tried, and the experience gained is such that it is expected that the project as approved can be carried out as soon as the river reaches a proper stage.

"Very respectfully, your obedient servant,

"AMOS STICKNEY,
"*Major of Engineers, U. S. A.*

"Lieut. Col. C. B. COMSTOCK,
"*Corps of Engineers, U. S. A.*,
"*President Mississippi River Commission.*"

"NEW ORLEANS, *January* 3, 1884.

"MAJOR: I have the honor to make the following report on the relative importance of protecting the Gouldsboro' bank, in the harbor of New Orleans, as compared with other work contemplated in the project approved by the Mississippi River Commission. The work contemplated by the Commission in the project approved by them September 18, 1882, was to prevent further erosion of the bank in Carrollton Bend.

"IMPORTANCE OF CARROLLTON BEND WORK.

"From a comparison of surveys I find that the bank in this bend is cutting away at an average rate of 14 feet a year, and the cutting extends probably 5,000 feet below the bend, all of which would probably be stopped in a short time after the bank in the bend is protected. The caving amounts to about 4.8 acres a year, which, at $1,000 an acre valuation for land and improvements, would be $4,800. If the caving is not stopped there will have to be built during the next five years 6,000 feet of levee,

estimated to cost $25,000, or $5,000 a year. The only business interests that suffer from caving banks are the Picayune saw-mill and the Carrollton oil-mill. The loss to them if the bank is not protected would probably be $35,000 during the next five years, or $7,000 a year.

"From the above the total loss per year from caving of bank in Carrollton Bend is $16,800. There are no wharves in Carrollton Bend, and the improvement would be of little benefit to commerce and navigation at present.

"IMPORTANCE OF PROTECTING GOULDSBOROUGH BANK.

"From my report of November 19, 1883, the value of land and improvements in the Gouldsborough bend which will be lost in a few years if the bank is not protected was estimated to be $1,400,000. But this does not represent the whole interest at stake. The river front here is being used for purposes of commerce and navigation, and these interests suffer very much from the caving in of wharves, railroad inclines, and depots.

"The commercial interest is much greater than the value of property already located there, and its value cannot be estimated.

"COMPARISON.

"The caving of bank in Carrollton Bend causes a very small loss of property compared to what it does in Gouldsborough Bend. The commercial interests in Carrollton Bend are almost nothing, while in Gouldsborough Bend they are very great and are rapidly increasing. It is important that the work at Gouldsborough be done soon, as the number of wharves and vessels landing at them is increasing, and they make the work of improvement more difficult. In order to make the city of New Orleans secure from danger of breaks in the levee and from being gradually washed away it is necessary to protect the bank in Carrollton Bend; but the immediate importance of the work is small compared to what it is at Gouldsborough.

"Respectfully submitted.

"W. G. PRICE,
"*United States Assistant Engineer.*

"Maj. AMOS STICKNEY,
"*Corps of Engineers, U. S. A.*

"NEW ORLEANS, *April* 17, 1884.

"MAJOR: In accordance with your request, I have the honor to make the following report on the plan for protecting the caving bank in the Gouldsborough Bend, in New Orleans Harbor, with submerged spurs.

"The portion of the bend which is now caving badly, and which needs immediate protection, extends from Periander street, in Gouldsborough, to Socrates street, in Algiers, and is about 5,000 feet long. The plan is to put down a number of submerged spurs each 300 feet long and built out at right angles to the bank; the spurs to be such a distance apart that the current deflected from one will reach the next before it strikes the bank. A mattress 350 feet by 200 feet will first be put down, and then four flexible brush cribs 5 feet high and 300 feet long, filled with rock, will be sunk one on another on the center line of the mattress, reaching to within 50 feet of the deep-water end of the mattress.

"METHOD OF CONSTRUCTING MATTRESS.

"The mattress will be constructed in position for sinking, and will be made of willow brush and poles, the brush to be woven on the poles, which will be 25 feet long and 8 feet apart, the longitudinal and transverse strength of the mattress to consist of iron rods, those which run parallel to the poles to be fastened to them, and to be in separate links of 25 feet, and joined with clevises; those which cross the poles to be made in a chain 350 feet long, with links of 8 feet, and to be connected with the clevises in the first system of rods; these chains to run through the mattress 25 feet apart, and to extend back on shore to logs sunk in the ground; the up-stream, down-stream, and deep-water edges of the mattress to be double in the thickness for a width of 8 feet, with a large quantity of rock between, which will be put in when the mattress is constructed. This will insure the ballasting of the edges of the mattress, and prevent their rising up and dumping the ballast. It is estimated that it will require 7.8 pounds of rock weighed in water to ballast a square foot of the mattress.

"METHOD OF CONSTRUCTING SPUR.

"In order to expedite the work so that it can be completed in one season it will be necessary to build the cribs at some point above, and float them down as they are needed for sinking. A few piles hauled out on shore will be sufficient ways for building the bottom of the crib. It can then be launched and finished on the water. It will be constructed of willow brush and poles, yellow-pine timber, and iron rods, leaving pockets into which the rock can be thrown for sinking it. The capacity of the pockets will be one-fourth of the size of the spur.

"It will be so constructed that when the iron rods rust away it will still hold together, and it will be so made that it can bend to the curve of the bank. The details of construction may have to be changed during the course of the work.

"METHOD OF SINKING SPUR.

"For sinking the spur two lines of barges will be required, one on each side of the spur; rock to be thrown in the crib until the pockets are full, and it will then be lowered to the bottom by ropes from the barges. To prevent the barges overturning, it will be necessary to build two longitudinal water-tight bulkheads in each, and the water will be let in on one side of the barge as the ropes pull down on the other. It may be necessary also to use a small quantity of rock as a counter-balance. The weight of a complete spur will sink one side of two 30-foot barges 2.4 feet.

"The buoyancy of a cubic foot of the spur will be about 7½ pounds, and to overcome this, and insure the stability of the spur, it will be necessary to use 15 pounds of rock weighed in water to the cubic foot of spur, which will require the spur to be constructed three-quarters of brush and one-quarter of stone. To give it increased stability, iron rods will run from the spur diagonally up-stream to the shore and be fastened to logs sunk in the ground.

"PLANT REQUIRED.

"The plant for the work should consist of six barges, each 30 by 124 by 7½ feet, decked, and containing two longitudinal water-tight bulkheads; three of the barges to have mattress-ways constructed on them, so that they can be placed end to end and a mattress 350 feet wide built on them. To do the necessary towing a steam-tug or stern-wheel steamboat will be required. The plant will be such that it can be used for any future mattress work in the harbor.

"COST OF THE WORK.

"To protect the bend at Gouldsborough, which is 5,000 feet long, it is estimated will require six submerged spurs. Calculating mattress to cost 4.13 cents per square foot, and the spur 5 cents per cubic foot—

Six submerged spurs will cost	$64,200
Six barges, at $3,000 each	18,000
To build mattress-ways on three of them	1,500
Ways built on the bank for constructing crib for spur	300
One stern-wheel steamboat	15,000
Capstans, rope, and tools	3,000
	102,000

"I present herewith the drawings accompanying this report.

"Respectfully submitted.

"W. G. PRICE,
"*Assistant Engineer.*

"Maj. AMOS STICKNEY,
"*Corps of Engineers, U. S. A.*"

"NEW ORLEANS, *April* 22, 1884.

"MAJOR: In accordance with your request I have completed a map of the Gretna Bend in New Orleans Harbor, showing the proposed improvement with submerged spurs. It is estimated that it will require six of these spurs to protect the bank in this bend; and estimating a spur to cost the same as given in my estimate for the protection in Gouldsborough Bend, it will require $64,200 for the work in Gretna Bend.

"No additional plant will be required.

"Very respectfully, your obedient servant,

"W. G. PRICE,
"*Assistant Engineer.*

"Maj. AMOS STICKNEY,
"*Corps of Engineers, U. S. A.*"

The necessity for protecting the bank in the Gouldsborough Bend being more pressing than that in the Carrollton Bend, the Commission authorized its commencement, which, on account of lack of sufficient funds, necessitated the stoppage of work at Carrollton.

The plan for the Gouldsborough protection is one which has not heretofore been tried on this river, but one from which I have strong hopes of good results. The main feature of the plan is the deflection of the current from the bank by means of spurs constructed of brush and stone. To prevent or lessen the eddies the spurs are submerged and sloping, and are placed on mattresses to prevent their being undermined.

The necessary working plant has been procured, contracts have been made for the material, and one spur is well under way.

Approximate estimate for completing work of improving harbor at New Orleans.

Carrollton Bend, left bank	$158,600
Gouldsborough portion of bend, right bank, 5,000 feet long	64,200
Gretna portion of bend, right bank, about 8,600 feet long	64,200
Bend above Gretna to a point nearly opposite the City Park, right bank, 26,400 feet	396,600
Total	683,600

The following report of Assistant Engineer W. G. Price is referred to for the details of the work:

"NEW ORLEANS, *October* 1, 1884.

"MAJOR: I have the honor to submit the following report of operations for the improvement of the harbor at New Orleans during the eleven months ending September 30, 1884:

"When I submitted my last report the work of protecting the caving bank in Carrollton Bend was in progress. The plan was to sink a continuous willow mattress 400 feet wide and 10,000 feet long. The contractor, Mr. George W. Davis, failed to furnish brush in sufficient quantities, which delayed the work to such an extent that on November 22 there were only 275 linear feet of mattress woven. On that date his contract was annuled, and arrangements for brush were made with Mr. J. H. Gardner. Under this arrangement some brush was received, and it was expected that work could be resumed with a strong force, but the rapid rise of the river made it hazardous to continue the construction of so large a mattress. All of the brush was woven in making a mattress 470 feet long.

"On December 7 preparations for sinking were commenced, and on the 12th the mattress was lowered to the bottom. Owing to a large quantity of drift-wood lodging under the mattress, considerable more rock was required than was expected, and as there was only a limited supply on hand, the last portion of the mattress to go down was not very heavily ballasted. During the night of the 12th a very strong current set in against this part and raised up a small portion of it.

"Additional rock was then purchased and part of this portion was forced down again; the remainder was torn to pieces by the current and floated away, about 4 per cent. of the mattress being lost.

"In sinking the mattress it was supported on the up-stream and down-stream edges by ropes to barges. These ropes were all marked with tags 4 feet a part. This made it possible to lower the edges of the mattress very evenly, as only 4 feet at a time was let out on each rope. The mattress was put down under great difficulties, as at times there was a very strong eddy which tended to twist the mattress out of shape. The success in putting down this mattress shows that it will be possible to put down a continuous mattress of that size, provided there are no large eddies. As there is a very strong eddy in Carrollton Bend when the river is rising, it will be necessary to stop work at such times. It also shows that to make sure of the mattress staying down and not curling up and beginning to break at the edges, it will be necessary to make the mattress double at the edge, with a heavy weight of rock between. A survey at Carrollton Bend was made during the month of November.

"It is estimated that to finish the protection of the bank in Carrollton Bend, which is now about 9,600 feet long, with a continuous mattress 400 feet wide, will cost $158,600.

"From a comparison of surveys the bank in this bend is now cutting away at an average rate of 14 feet a year, and the cutting extends about 5,000 below the bend, all of which would probably be stopped in a short time after the bank in the bend is protected. It is estimated that the total loss per year from caving of this bank is $16,800.

"There are no wharves, and the improvement would be of little benefit to commerce and navigation at present.

"In order to make the city of New Orleans secure from danger of breaks in the levee, and from being gradually washed away, it is necessary to protect the bank in this bend, but the immediate importance of the work is not so great as it is in other portions of the harbor.

"On November 19, 1883, in accordance with your order, I obtained the following information in regard to the caving banks, values of property and interests on the river front in Gouldsborough and Gretna:

"The bank along some parts of this front is caving badly. It is occupied for railroad termini, transfer facilities, warehouses, and similar constructions. These are all used for purposes of commerce and navigation, and they cannot be safely used unless the bank is protected. The value of property on this front is estimated to be $1,400,000. The interests at stake are far greater, and cannot be estimated. The length of the bank to be protected here is about 13,600 feet, but the work to be permanent must in time be carried round the whole bend, which is about 40,000 feet long. The protection adopted for Carrollton Bend is not suited for work in this bend, owing to the difficulty in laying a continuous mattress where there are wharves in constant use, and the probability that the mattress would be wrecked by the sliding down of wharves under which a bank of silt had collected. The improvement must be such that the slope of the bank from low-water mark to the bed of the river shall become about 3 to 1: then if a mass of silt collect under the wharves it will not be likely to slide down the bank and wreck the improvement.

"The protection proposed by you for this part of the harbor consists of a system of submerged spurs, built out at right angles to the bank, and from 500 to 1,600 feet apart.

"The spurs to be built out on a slope of 3 to 1 and to be such a distance apart that the current deflected from one will reach the next before striking the bank. It is estimated the cost of protection will be as follows, exclusive of plant:

Gouldsborough portion of bend (5,000 feet long)	$64,200
Gretna portion of bend (8,600 feet long)	64,200
Bend above Gretna (26,400 feet long)	396,600
Cost of protecting the whole bend	525,000

"The plant used in Carrollton Bend can be used for the work, and there will be required in addition three decked barges and a stern-wheeled tow-boat.

"It having been decided to begin the work of putting down submerged spurs at Gouldsborough, plans and estimates were prepared. Three decked barges were constructed by contract and delivered August 28. The plant in use last season has been improved and put in order for the new work.

"A survey of the Gouldsborough portion of the bend was completed in July. On August 23 the stern-wheel tow-boat Annie Kelley was purchased; she has been employed in towing barges of rock from Wilson's Point to Gouldsborough. On August 24 the plant was towed to Gouldsborough, and on the 29th the constructing of the first mattress was begun.

"The mattress for the spur is 200 feet wide, up and down stream, and extends 350 feet out in the river. Just above the center line of this there will be sunk, one on another, six cribs 5¾ feet thick, the bottom one having a width of 60 feet and the top one a width of 20 feet. The bottom one will be short and they will increase in length so that the top of the last one will be on a slope of 3 to 1 from low-water mark. Owing to the slow delivery of material the mattress was not completed till September 12. On September 15 this mattress was successfully lowered to the bottom. It has cribs filled with rock attached to three sides of it. The crib on the upper side is inclosed so that the rock cannot get out of it. On September 20 the first crib was launched into the river. They are being constructed on ways which are built on the river bank. The first crib was ballasted and lowered to the bottom successfully on September 27.

"It is proposed to put down six spurs in the Gouldsborough portion of the bend, which it is thought will give all the protection required.

"Respectfully submitted.

"W. G. Price,
"*Assistant Engineer.*

"Maj. Amos Stickney,
"*Corps of Engineers, U. S. A.*"

MONEY STATEMENT.

In Treasury Department, Washington, D. C., July 1, 1882		$144,525 90
Drawn	$136,000 00	
Transfer and deposit	12,826 25	
		123,173 75

Not drawn, September 30, 1884		$21,352 15
On hand, assistant treasurer, New Orleans, July 1, 1882		3,267 91
On hand, assistant treasurer, New Orleans, September 30, 1884		22,997 61
In hands of assistant to September 30, 1884		1,053 31
Available September 30, 1884		45,403 07
Balance due from appropriation, October 31, 1883		5,577 10
Received since October 31, 1883	$136,000 00	
Transfer and deposit		12,826 25
Expended since October 31, 1883		93,545 73
On hand September 30, 1884		24,050 92
		136,000 00
Total available since July 1, 1882		147,793 81
Total expended since July 1, 1882		102,390 74

Condensed list of plant for which Maj. Amos Stickney, Corps of Engineers, U. S. A., is responsible, and its present estimated value.

HARBOR AT NEW ORLEANS, LOUISIANA.

1 boat, steam (stern-wheel)	$14,325 00
1 boat, tug (steam)	4,500 00
1 launch (steam)	2,700 00
15 barges	21,500 00
1 barge, coal	40 00

MOUTH OF RED RIVER, LOUISIANA.

2 boats, quarter	$3,500 00

HARBOR AT NATCHEZ AND VIDALIA.

4 boats, flat	Almost valueless.

CUBITT'S GAP.

Total allotted	$300 00
Total drawn	300 00
On hand, assistant treasurer, New Orleans, La	162 86
Expended to September 30, 1884	137 14

OBSERVATIONS AT CARROLLTON.

Total allotted	4,500 00
Total drawn	4,500 00
Total expended	4,454 11
On hand, assistant treasurer, New Orleans, La	49 89

UNLEVEED FRONTS.

Total allotted	1,000 00
Total drawn	1,000 00
Total expended	902 12
On hand, assistant treasurer, New Orleans, La	97 88

Very respectfully, your obedient servant,

AMOS STICKNEY,
Major of Engineers, U. S. A.

Lieut. Col. C. B. COMSTOCK,
Corps of Engineers, U. S. A.
President Mississippi River Commission.

APPENDIX K.

REPORT OF CAPTAIN E. H. RUFFNER, CORPS OF ENGINEERS, UPON THE IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE DES MOINES RAPIDS AND THE MOUTH OF THE ILLINOIS RIVER.

UNITED STATES ENGINEER OFFICE,
Quincy, Ill., October 17, 1884.

SIR: In compliance with your circular calling for an annual report of the operations in the "improvement of the Mississippi River between the Des Moines Rapids and the mouth of the Illinois River," up to October 1, 1884, I have the honor to forward herewith copy of the annual report of Maj. A. Mackenzie to July 1, 1884, and to supplement his report by a brief one of my own, to cover the period from July 1 to October 1, 1884.

Understanding it to be your wish that the report be as concise as possible, I have not forwarded the reports of Major Mackenzie's assistants, which can be sent you if desired.

Having reported at Rock Island, Ill., August 14, and assumed charge, after an inspection of the river, on September 1, I am really only able to report of the intervening period to end of September; but as the principal work was done that month, perhaps all that is required will be found.

Very respectfully, your obedient servant,

E. H. RUFFNER,
Captain of Engineers.

IMPROVEMENT OF THE MISSISSIPPI RIVER FROM DES MOINES RAPIDS TO MOUTH OF ILLINOIS RIVER.

With this general appropriation, works for the benefit of through navigation are carried on at localities selected each year as being in greatest need of improvement.

During the past fiscal year improvements have been carried on by formal contract at Louisiana, Mo., and Quincy, Ill., by informal agreement at Gilbert's Island and vicinity, and by aid of the Government plant at Alexandria, Quincy, Marion City, Hannibal, Canton, Howard's, Gilbert's Island, Denmark Island, and Dardenne Island.

The details of this work are given in the reports of Assistants Meigs, Hoffman, Durham, and Chaffee. Allotments have been made from this appropriation for the snag-boat service, the removal of wrecks, surveys, and additions to plant.

The work at all points, excepting Howard's, has been of the same character as that heretofore carried out and fully described in previous reports. At Howard's Bar, between Canton and La Grange, Mo., a Government dredging outfit was used in connection with the formation of a new channel and the construction of dams. Howard's (or Smoot's) Crossing, always one of the worst between Keokuk and Saint Louis, threatened, during the fall of 1883, to seriously interfere with navigation. A cut about 1,000 feet long, 110 feet wide, and of a depth of 5 feet at extreme low water, was made through the bar in about a week, and at comparatively small expense.

Eleven thousand one hundred and ninety cubic yards of material were removed by the dredge. This cut remained open and furnished a good channel throughout the season of low water.

After the completion of the cut the dredge supplied, from a gravel bar, material for the construction of two wing-dams similar to the one constructed at Hannibal in the spring of 1883.

While the first wing-dam was under construction the swift current caused the gravel to spread over a very wide area, and to obviate this waste of material appliances for checking the current during time of construction were subsequently used. The small amount of money available for work during the year and the late day at which it was permissible to make use of the Government dredge cut short the season of operations in the vicinity of Howard's, but enough work was done to fully establish the fact that dams can be constructed of gravel more rapidly and at a much less cost than those built of brush and rock. This class of work will be resumed when future appropriations will permit, and before the close of the present season it is expected that important results and information will be secured.

Trouble being anticipated at Mundy's Crossing, 18 miles below Hannibal, during the period of low water of last season, a cut 60 feet wide, 6 feet deep, and about 200 feet long was made in thirty-six hours by a hired dredge. After this cut was opened no difficulty was experienced at this point.

The experience of the past season has shown that much assistance can be given to navigation by this kind of work, which, though temporary in a certain sense, is likely to be permanent for one season, if not longer. By the temporary use of dredges

at an expense so comparatively small as to be fully justifiable, I have no doubt a good navigable channel can be maintained during the low-water season on this stretch of the river, and if the navigation of the river is to be continued with success by steamboats, such temporary aid must be given until such time as the permanent channel improvement is completed. It is proposed to furnish as much aid in this direction during the coming season as circumstances permit.

The funds available have not permitted work to be carried on during the past year at the Government quarry at Dixon's Landing, but a portion of the rock in store at that point was used in connection with improvements near Quincy, Ill. A large amount of rock is still on hand, and will be used during present season. This quarry is an important adjunct of the work of river improvement, insuring as it does, when other sources fail, a steady and ample supply of rock at a reasonable cost.

The greater part of the work of the past fiscal year was carried out late in the season of 1883, and results attained cannot be given until the low-water season of present year arrives.

At points where former improvements were made, no trouble has been experienced during the past year, even at the lowest stages. A sketch showing the favorable results attained below the Louisiana Bridge is appended.

The system of improvement now being carried out between the Des Moines Rapids and the mouth of the Illinois River, which consists in closing side chutes and reducing the stream to a uniform width, will in time accomplish all the results claimed for it, and that this system is generally indorsed, and has greatly benefited commerce, is conclusively shown by the report of the select Senate committee, published in Senate Doc. No. 36, Forty-second Congress, first session.

The point which is now especially aimed at is such improvement in the methods of constructing wing and closing dams and shore protections, as will reduce their original cost, and do away with the expense attending repairs, &c., and at the same time admit of more rapid construction.

No funds have been available for resuming work in 1884, excepting in the vicinity of Quincy, Ill. During the past winter the plant pertaining to this appropriation has been put in good order, and is now ready for use.

Summary of expenditures for fiscal year ending June 30, 1884.

Quincy revetment	$24,325 47
Vicinity of Louisiana	44,890 71
Repairing dam at Alexandria	1,619 92
Marion City and Hannibal	13,934 83
Repairs at Gilbert's, Denmark, and Dardenne islands	23,987 04
Dredging and building gravel dams at Howard's	5,613 50
Quincy (dams 1, 2, and 3)	1,577 54
Repairs at Canton and Smoot chutes	4,592 56
Removing wrecks at Hamburg, Keokuk, and Quincy	1,332 07
Purchase and repairs of plant	15,018 36
Snag-boat General Barnard	348 33
Surveys and gauges	502 12
	137,742 45

NOTE.—Of above amount, $5,978.82 was reported as outstanding liability July 1, 1883.

Expenditures on the various sections of the river between Des Moines Rapids and the mouth of the Illinois River from commencement of improvement to July 1, 1884.

Des Moines Rapids to Quincy Bridge (40 miles)	$80,653 58
Quincy Bridge to Saverton (25 miles)	49,352 76
Saverton to Louisiana Bridge (25 miles)	198,703 77
Louisiana Bridge to Hamburg (25 miles)	96,788 04
Hamburg to Illinois River (48 miles)	41,968 30
Surveys and gauges	38,363 35
Snag-boats and wrecking	23,784 36
Material and Government quarry	29,538 82
Plant at estimated value	43,253 78
	602,406 76

As the Government is now provided with the plant and outfit needed for carrying on extensive operations, and as an economical method of working requires liberal appropriations, it is hoped that this section of the river may be granted the sum of $1,000,000 for the fiscal year ending June 30, 1886.

ABSTRACT OF APPROPRIATIONS.

By act approved June 18, 1878	$100,000
By act approved March 3, 1879	40,000
By act approved June 14, 1880	100,000
By act approved March 3, 1881	175,000
By act approved August 2, 1882	200,000
	615,000

A true copy.

A. MACKENZIE,
Major of Engineers.

A true copy.

E. H. RUFFNER,
Captain of Engineers.

Lieut. Col. C. B. COMSTOCK,
Corps of Engineers,
President Mississippi River Commission.

IMPROVING MISSISSIPPI RIVER BETWEEN DES MOINES RAPIDS AND MOUTH OF ILLINOIS RIVER, JULY 1, 1884, TO OCTOBER 1, 1884.

(Major A. Mackenzie, Corps of Engineers, in charge to September 1, Captain E. H. Ruffner, Corps of Engineers, in charge September 1 to October 1.)

During July no new work was done, the operations in construction being confined to the raising and repairing of the dams opposite Quincy, Ill., known as 2.68 and 3.68, in which works were used 1,438 cubic yards of stone.

The project of expenditure for the new appropriation having been approved August 1, work was begun first by continuing the shore protection of Buffalo Island, below Louisiana Bridge, under the contract with Patterson Bros., dated November 9, 1882, and the raising of a low place in the wing-dam built from the shore opposite the foot of Buffalo Island. This work was satisfactorily completed August 30. An agreement was made with Mr. H. L. Brown, at 25 cents per cubic yard for dredging gravel and putting in a foundation 3 feet deep for a closing dam between Brokaw Island and the Illinois shore. This work began in August and was finished October 15, and the material used amounted to—

19,760 cubic yards, at a cost of	$4,940
15 piles, at a cost of	60
	5,000

To complete this work, that is to put in the shore protection at the head of Brokaw Island and the brush and stone dam on top of this foundation, bids were opened September 1, 1884, of which the following is the abstract:

Number	Names and residences of bidders.	10,000 cubic yards of stone. Price per cubic yard.	Amount.	8,000 cubic yards of brush. Price per cubic yard.	Amount.	Aggregate.
1	Fruin, Bambric & Co., Saint Louis, Mo	$1 49	$14,900	$0 80	$6,400	$21,300
2	H. McPherson & Co., Boonville, Mo	1 49	14,900	85	6,800	21,700
3	C. S. Whitney, Keokuk, Iowa	1 35	13,500	90	7,200	20,700
4	N. J. Whitney, Keokuk, Iowa	1 49	14,900	80	6,400	21,300
5	H. S. Brown, Quincy, Ill	1 40	14,000	91	7,280	21,280
6	Patterson Bros., Keokuk, Iowa	1 35	13,500	65	5,200	18,700

Contract was made with Patterson Bros., of Keokuk, Iowa, for this work at the above figures, and work began at once, September 24, and some small amount was done before the close of the month. Mr. J. C. McElherne has acted as the inspector for the works in this vicinity, and will for the new work contracted for by Messrs. Patterson.

On August 3 instructions were given Assistant Engineer E. F. Hoffman to begin work with United States dredge No. 2, tow-boats 3 and 4, and suitable barges, &c., on a closing dam between the Illinois shore and the island, No. 421, opposite La Grange. This work was in immediate charge of Assistant Engineer W. A. Thompson; Assistant Engineer Hoffman died August 13. After that time Assistant Engineer O. N. Chaffee exercised a general supervision over this work, as well as over that done by the Coal Bluff and plant.

The closing dam was built somewhat differently from ordinary, there being a line of piles and sheet piling used as principal obstruction to the flow of water through the slough. Strengthened by the use of mats, gravel, and of stone, it was hoped the dam would answer its purpose, and be more economical than other methods used. Time will show as to this. This dam was completed September 17. A wing-dam was then begun, about 2,000 feet below wing-dam 3.66, half way between Canton and La Grange, and was fairly under way at the close of the month. The effects of these new works are not as yet evident, owing to their recent construction and continued high water, but it may be said that the bar above La Grange is evidently cutting and the channel straightening.

The steamer Coal Bluff (U. S. No. 5) was prepared for service September 1, and started from Keokuk for work near Dixson's Landing with part of her plant. It was found, however, that she leaked badly and she was placed on the ways at Quincy. This, and a delay in getting her off from the ways, postponed the beginning of the work until the middle of the month. Since then she has been engaged in putting in shore protection at Bolter's Island, and in preparing to put in a dam from the island to the tow-head, a work which will be about 300 feet long. This work is under the immediate charge of Assistant Engineer C. M. Bennett.

Continuous high water in September and since then has made the works of construction more tedious and expensive than usual, and have hindered necessary surveys to determine the effects of previous works.

Assistant Engineer O. N. Chaffee has assisted me in the purchase of supplies, the inspection of work and the general management of working parties, and in carrying out the plans of Major Mackenzie, as set forth in the approved project.

Bids were opened September 5 for dredging in Quincy Bay in accordance with the terms of the appropriation, which allotted $12,500 for this purpose. The contract was assigned to H. S. Brown, after C. L. Williams who had made an equally low bid, had resigned in his favor.

The abstract of proposals is given below:

Number.	Names and residences of bidders.	For dredging and removing material to a distance not exceeding 1 mile. Approximate quantity, 15,000 cubic yards.	For dredging and removing material to a distance exceeding 1 mile and not exceeding 2½ miles. Approximate quantity, 45,000 cubic yards.	Total.
		Per cubic yard.	*Per cubic yard.*	
1	J. W. Heisey, Burlington, Iowa	$0 15	$0 21	$11,700 00
2	C. S. Whitney, Keokuk, Iowa	10¾	21	12,421 25
3	C. L. Williams, Keokuk, Iowa	14	14	8,400 00
4	A. J. Whitney, Keokuk, Iowa	12	15	8,550 00
5	H. S. Brown, Quincy, Ill	14	14	8,400 00
6	B. E. Linehan, Dubuque, Iowa	22	23	13,650 00

ESTIMATED VALUE OF PLANT.

Coal Bluff, United States tow-boat No. 5	$10,000
6 new barges, at $3,000	18,000
3 old barges, at $1,200	3,600
1 old barge	500
1 coal flat	1,200
1 pile-driver and tender	1,800
3 quarter-boats, two at $1,800 and one at $500	2,300
1 launch, Irene	1,500
1 dredge, United States No. 2	25,000
6 dump boats, at $1,000	6,000
	69,900

FINANCIAL STATEMENT.

Appropriation, July 5, 1884		$200,000 00
Amount expended to October 1, 1884	$18,251 35	
Amount contracted for with Patterson	18,700 00	
Amount contracted for with H. S. Brown	8,400 00	
		45,351 35
Balance available October 1, 1884		154,648 65

APPENDIX L.

REPORT OF MAJOR O. H. ERNST, CORPS OF ENGINEERS, UPON THE IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., October 17, 1884.

SIR: In compliance with the instructions contained in your circular of September 17, 1884, I have the honor to submit the following annual report for works executed from funds controlled by the Mississippi River Commission, the report being brought down to October 1, 1884, "for the portion of the river under my charge, viz, between the Illinois and Ohio rivers."

This portion of the river came under the control of the Commission by a provision in the river and harbor act of July 5, 1884. Up to that time operations had been carried on under the Chief of Engineers, United States Army, being regularly described in my annual reports, the last of which gives their history for the fiscal year ending June 30, 1884. Upon the 8th of August I received notice that my project for the expenditure of the new appropriation, the first one under the control of the Commission, was approved. At that time the works had been suspended for about two months, nearly all supplies had been exhausted, and the laboring force was disbanded. Although preparations for the procurement of supplies and the reorganization of the force had already been begun, and no time has since been lost in this office, these preparations are not even yet entirely completed. The works under the new appropriation may therefore be said to be only fairly inaugurated. My report upon this occasion will therefore necessarily be brief. The works consisted entirely of the repair or extension of those begun in former years, with the exception of the one at Cairo, Ill.

ALTON.

The dike opposite and above the landing at Alton had accomplished the desired result of improving the landing, but there had been considerable settling in some portions of it. To preserve its efficiency it was considered desirable to fill up the depressions, and to raise the general level of its crest to the height originally fixed upon—14 feet above low water. This work was begun in August. By the 1st of October a length of about 1,680 feet had been raised to the required height, and good progress had been made in raising other portions. The work was temporarily suspended at that time, on account of high water. The expenditures were $4,915.40, making the total cost of the dike to that date $72,240.10.

ARSENAL ISLAND.

The protection of the west side of Arsenal Island had been put in at various dates, beginning with 1877. The portion near the head of the island was unprovided with a mattress at the foot of the slope. It was considered necessary to place such a mattress, in order to secure the old work from injury, and an extension of the whole, about the head of the island, had become necessary. The work was begun August 12, and completed September 19. A mattress 120 feet wide and 1,283 feet long was placed below low-water mark, its up-stream extremity being about 300 feet above the terminus of the old work. Riprap was deposited upon the bank, above low water, over this length of 300 feet, and about the head of the island to a distance of about 100 feet on its eastern side.

HORSETAIL.

The new bank built up by the work of former years, upon the west or Missouri side of the river, had been partially protected on its channel side, the mattress having been placed at the foot of the slope, and riprap deposited above low-water mark

to a height of about 6 feet. This protection has been extended this season to a height of about 21 feet above standard low water, for a length of about 1,150 feet. A portion (about 366 cubic yards) of the stone used was obtained from the old dike No. 1. Upon the Illinois side, the two new hurdles, called 27½ and 29½, which had been constructed to a length of 1,325 and 1,450 feet, respectively, from the Illinois shore, were extended to their full length of 2,055 and 2,135 feet, respectively, and were nearly completed. A new hurdle, to be called No. 31, was laid out about 1,000 feet below No. 30, but only a few piles (eight) had been driven October 1. The good results heretofore secured have been maintained during the recent low-water season, the least depth found being 9 feet.

TWIN HOLLOWS, WEST SIDE.

Very heavy deposits were secured at this locality during the summer rise. Some repairs were required in the primary hurdle and in secondary hurdles 1, 4, and 5. Those in No. 1 were completed, and those in the primary hurdle nearly completed, and those in No. 4 were begun. The good results heretofore secured by these works, in connection with those at Pulltight, were maintained throughout the recent low-water season, the least depth found in the channel being 9 feet. The lower crossing has been pushed down-stream sufficiently far to justify the beginning of another secondary hurdle, No. 6. The process of straightening the channel is working very favorably.

TWIN HOLLOWS, EAST SIDE.

The river having shown a tendency to attack the bank at a point lower down than where the protection of former years had been placed, it became necessary to extend the latter down-stream. This work was begun early in September. A mattress 120 feet wide, to be placed below low-water mark, was begun, and by the 1st of October had reached a length of 990 feet. The old work stands intact.

PULLTIGHT.

Work at this locality was begun in the latter part of August. Hurdle No. 5, which required only the wattling to finish it, was completed, and No. 4, 1,770 feet long, was begun and by the 1st of October was well advanced towards completion. These works have contributed towards the good results above reported for Twin Hollows, west side.

"JIM SMITH'S."

The most extensive works of the season are being carried on at this locality, but as they consist simply of reconstructing the old hurdles and decreasing the interval between them, by the construction of new ones midway between the old; they may be described in small space.

Work has been prosecuted upon Nos. 3½, 4, 4½, 5, 5½, 6, 6½, 7, and 7½. Of these, 4, 4½, and 5 were well advanced toward completion on 1st of October; 3½ and 6 were only fairly begun, and good progress had been made upon the others. The least depth found in the channel during the recent low-water season was 7½ feet and was found opposite Chesley Island.

CAIRO PROTECTION.

The river and harbor act of July 5, 1884, in the item appropriating $520,000 for this district, provided as follows, viz: "$50,000 of which sum shall be used in extending the works for the protection of the easterly bank of the Mississippi River at Cairo, Ill., and the prevention of its wash or erosion, commencing at the southerly end of the present Government revetment work, and continuing down-stream." The locality thus specifically described is shown upon the inclosed sketch. A series of spur-dikes were constructed here some thirty years ago by the Cairo Land Company. They have had the usual effect of spur-dikes built in a rapid-flowing stream with a soft bottom. Deep excavations have been made between them, and in the case of two or three at the up-stream end of the series, they have been cut off from the bank and have disappeared. Those that remain have been the subject of repair at intervals ever since their construction, and large quantities of stone have been placed upon the bank between them. These re-enforcements have usually been made under pressure, when the river was high and threatening. The material was thrown in where it seemed to be most required, without much system, and without any record of where it was deposited. It is uncertain how much of the slope below the water-surface is covered, but it is to be supposed that much of that between the spurs is not safe from undermining. It was accordingly determined to place a continuous mattress of the

standard width 120 feet outside of and embracing all the spurs and intervals between them, the inner edge of the mattress being placed as nearly as practicable on the low-water line. The jagged outline of the bank rendering necessary sharp curves in the mattress, and the swift currents about the ends of the spurs having a velocity in some cases of 8 feet per second, have made this a difficult piece of work. By the 1st of October the mattress had reached a length of 1,012 feet, of which 250 feet at the up-stream end had been sunk. The cash expenditures were $5,511.51, to which should be added $1,916.67 for the use of plant.

The cash expenditures for the works other than Alton and Cairo were $77,612.23. As these works are being carried on with one plant, and are being supplied from a single base, it is impracticable to give the expenditures for each one separately within the time fixed for rendering this report, viz, October 20.

Very respectfully, your obedient servant,

O. H. ERNST,
Major of Engineers.

Lieut. Col. C. B. COMSTOCK.
Corps of Engineers, U. S. A.,
President Mississippi River Commission.

Estimated value of plant October 1, 1884.

Steamer Humphreys	$20,663 45
Steamer Gillmore	19,360 25
Launch Hornet	224 96
Launch Florence	775 00
Barges, barge flats	42,098 07
Pile-drivers	39,867 15
Quarters, shops, &c	29,571 65
Quarter-boats	4,713 48
Skiffs, &c	7,662 18
Tools and appliances	6,950 92
Hydraulic excavator	5,825 63
Ways for mattresses	4,081 69
Photographic apparatus	339 51
Office furniture	905 87
Surveying instruments	1,101 67
Boarding outfit	12,692 14
Total	196,833 62

APPENDIX M.

REPORT OF THE BOARD OF ENGINEER OFFICERS UPON THE ALLOTMENT OF FUNDS FOR THE PRESERVATION AND REPAIR OF UNITED STATES LEVEES ON THE MISSISSIPPI RIVER.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., August 27, 1884.

SIR: The Board of Engineer Officers convened by Special Orders No. 100, headquarters Corps of Engineers, United States Army, Washington, D. C., August 11, 1884, to make recommendations for the division of the remaining $160,000 of the allotment for the preservation and repair of levees among the United States levees on the Mississippi River needing repairs and completion, have the honor to make the following report:

The Board met at Memphis, Tenn., August 25. It consisted of Maj. Amos Stickney and Capt. C. B. Sears; Maj. A. M. Miller, Corps of Engineers, having been relieved from the Board by Special Orders No. 188, headquarters of the Army, Adjutant-General's Office, Washington, D. C., August 12, 1884.

The Board remained in session three days, carefully considering the whole question before it, and listening to written and verbal statements and petitions laid before it by the engineers and members of the various State Levee Boards and representative citizens of the various places along the river immediately interested in levee work.

From the best obtainable data it was found that for the repairs in United States evees, to close gaps only, and to provide for raising the Lake Concordia Levee 1 foot, made necessary by the King's Point Cut-off, there would be required the following lamounts of earthwork, viz:

YAZOO FRONT, SECOND DISTRICT.

	Cubic yards.
Garth and McCloud breaks	140,000

TENSAS FRONT, THIRD DISTRICT.

Duffin break	20,000
Panther Forest	271,000
Raleigh to Willow Point	186,000
Delta to Bedford	24,000
Total	501,000

TENSAS FRONT, FOURTH DISTRICT.

Point Pleasant breaks	30,000
Ship's Bayou to Hard Times	43,139
Hardscrabble to Bondurant	177,388
Kempe Levee	108,119
Lake Concordia	150,000
Total	508,646

A total yardage of 1,149,646 cubic yards, estimated to cost $345,000.

Having only $160,000 with which to accomplish this work, the Board thought best to throw out such breaks as could not be filled entirely, and which by being only partially filled would be of little good by reason of breaks above or below.

The Board recommends, therefore, the following division and allotment of the $160,000:—

For preservation and repairs of United States levees in Yazoo Front, second district, $20,000, provided the Levee Board of the first levee district of Mississippi is enabled and will guarantee to expend $500,000 on its levees in said district. In case, however, guarantees for the expenditure of this amount are not given by September 10, 1884, or, in case it be definitely stated by the Levee Board of said district, or its engineer, before said date, that it will be unable to expend the amount of $500,000, then it is recommended that this $20,000 aforesaid shall be allotted for repairs to United States levees in the Yazoo Front, third district.

For preservation and repairs to United States levees in Tensas Front, third district, $50,000.

For preservation and repairs to United States levees, Tensas Front, fourth district, $90,000.

AMOS STICKNEY,
Major of Engineers, U. S. A.
CLINTON B. SEARS,
Captain of Engineers, U. S. A.

The CHIEF OF ENGINEERS, U. S. A.,
Washington, D. C.

W W 2.

REPORT FOR 1885.

THE MISSISSIPPI RIVER COMMISSION,
PRESIDENT'S OFFICE,
New York, July 15, 1885.

SIR: The Mississippi River Commission has the honor to submit the following report, embracing the subjects and subdivisions specified below, to wit:

(1) Progress of surveys and examinations from October 1, 1884, to June 30, 1885.
(2) Progress of construction from October 1, 1884, to June 30, 1885.
(3) Plan and methods of improvement discussed.
(4) The Atchafalaya Outlet.
(5) Vicksburg Harbor.
(6) Legislation recommended.
(7) Financial statements and estimates of funds for the fiscal year ending June 30, 1887.

PROGRESS OF SURVEYS AND EXAMINATIONS.

The surveys and examinations undertaken in pursuance of the requirements of the third section of the act under which the Commission was organized have been continued.

In the last annual report, progress in this branch of work was noted to October 1, 1884. From that date to the end of the past fiscal year work has been accomplished in field and office as follows:

Gauges.—Daily readings have been taken and displayed at all stations previously established, up to the end of April last, at which time those at Cliff, Mo., Cottonwood Point, Mo., Mhoon's Landing, Miss., Saint Louis Landing, Ark., Saint Joseph, La., Port Hickey, La., and Plaquemine, La., were discontinued. A lack of funds made a reduction needful, and these were regarded as the least important or the most difficult to maintain in good order.

The reading of the gauge at Biloxi, established last season for the purpose of determining the mean level of the Gulf, ceased with June 10, 1885, a full year of observations being obtained.

Final topography and hydrography.—The survey of the river, with marginal topography, which at the date of the last report was complete from Cairo to the Gulf, and from Grand Tower to Devil's Island, was prosecuted from the latter point and completed to Hacker Towhead, about 25 miles farther, when cold weather put a stop to field work, and want of funds has prevented its further prosecution.

Discharge observations.—Six parties, at as many localities, were kept in the field from the end of September, 1884, till early in April, 1885, when they were withdrawn because of lack of funds.

Preparation of maps.—Work on the preliminary chart (1 inch to a mile) has been continued. The complete series, comprising 32 charts, has been printed, excepting the index charts, now nearly ready. Nine sheets of the series on a scale of 1 to 20,000 are printed. The material

WORKS BELOW CAIRO.

FIRST DISTRICT.

NEW MADRID AND PLUM POINT REACHES, 220 MILES.

Since the last report work in this district has been confined to the Plum Point Reach, and has been conducted in accordance with the general project described in the report of the Commission for 1883.

The works of contraction at Gold Dust, Plum Point, and Bullerton have been repaired and extended, and foot-mats have been sunk along the faces of the principal lines.

Mattress work and upper bank revetment were vigorously prosecuted to the close of the season at Fletcher's Field, Osceola Bar, Bullerton Towhead, and Craighead Point. The revetment work has remained in generally good condition, except at Craighead Point, where, although the foot mattresses appear to have kept in place, the upper bank revetment has disappeared.

This last work was undertaken in an emergency to protect a caving bank, was prosecuted under great difficulties, and was suspended before completion when severe cold weather prevented the delivery of stone. The general effect of the contraction works in this reach has been good, the main channel from Plum Point giving 12 feet depth. The deposits within the areas inclosed by the dikes have continued, although there has been no rise of any considerable duration. Bullerton Chute is filling up rapidly and the average fill within the Plum Point lines is about 15 feet. The fill within the Gold Dust system has continued, being in many places considerably above low water. It is especially noted that the old channel cut off by the main dike near Cross-dike No. 1 has closed, changing from a depth of 33 feet at low water to a height of about 12 feet above low water, since October, 1884, a fill of about 45 feet, obtained mostly in one small flood.

Losses in this district have been confined chiefly to the earlier work, the dikes and revetments of later construction having suffered but little damage when completed and secured before floods set in. The present value of the plant used in this district is estimated at about $308,000. The expenditures during the time covered by the report were about $350,000, and the balance available July 1 is about $18,000. Special attention is invited to the remarks and suggestions in the report of Captain Leach, to which, with that of Assistant Notly, reference is made for details. (Appendices G and G 1.)

SECOND DISTRICT.

MEMPHIS REACH AND HARBOR, 180 MILES.

Work in this district was confined to the revetment of Hopefield Bend and of the caving bank of the Memphis City Front, Congress having specially provided $200,000 for the protection of Memphis Harbor. The work on the city front consists of wide continuous mattresses extending from low water to the foot of the slope, 250 to 300 feet, and substantial upper bank revetment, carried above high-water mark. The total length of revetment is about 4,700 feet, the submerged mattresses extending from the mouth of Wolf River about 1,600 feet down-stream.

The entire work has withstood the effects of ice and this season's high water and appears to be secure. Work in Hopefield Bend consisted in the repair of breaks, the extension of the upper bank revetment for about 3,000 feet, and construction and sinking of about 3,000 feet of mattresses 150 feet wide. The work in Hopefield Bend has stood quite well. There have been several small breaks in the bank, due to slips, and about 2,000 feet of partial upper bank revetment, built in 1883, but not carried above high-water mark, have been lost. The continuity of the foot-mattress work appears to be unbroken.

The severe criticisms that have been indulged in concerning the Memphis and Hopefield Bend revetments do not seem to be justified by the facts.

The present value of the plant used in this district is estimated at about $97,000. The expenditures in this district during the time covered by the report, including $15,000 for levees, were about $228,000, and the balance available July 1 is about $1,500. Special attention is invited to the remarks of Captain Leach on the revetment of Memphis Front, to whose report and that of Assistant Rees, reference may be had for details. (Appendices H and H 1.)

THIRD DISTRICT.

LAKE PROVIDENCE REACH AND VICKSBURG AND GREENVILLE HARBORS, 220 MILES.

Before this improvement was undertaken the navigation of Lake Providence Reach was poor, the depth in low water being reduced frequently to 5 feet.

The general project consisted in preventing dispersion by closing the chutes and reducing the low-water width to about 3,000 feet by the construction of permeable dikes and the formation of artificial banks by deposit, and the preservation of the natural curves of the river by revetting caving banks. This reach has been improved so that there is now a navigable depth of 15 feet throughout its length. The greater portion of the work done in this district since October 1, 1884, has been the extension of the revetment in Louisiana Bend (Pilcher's Point), the repair of revetment at Mayersville, and the revetment of Delta Point, Louisiana.

No additional works of contraction were undertaken, operations having been limited to repairs of former work, the construction of three cross-dikes in chutes, and raising the screen work on main lines. The necessity for holding Louisiana Bend and Delta Point has been stated in former reports, but is briefly repeated again on account of their importance.

The caving of Louisiana Bend must be prevented in order to maintain the improvement of Lake Providence Reach, and Delta Point must be held both to maintain the regimen of the river for considerable distances above and below, and to prevent further recession of the river from Vicksburg.

The present value of the plant used in this district is estimated at $340,000. The expenditures (including levees) during the time covered by this report were about $447,000, and the balance available July 1 was about $26,000.

For details reference is made to the reports of Captain Sears and Assistant Hider, Appendices I and I 1.

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The present value of the plant used in this district is estimated at $340,000. The expenditures (including levees) during the time covered by this report were about $447,000, and the balance available July 1 was about $26,000.

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FOURTH DISTRICT.

HARBORS OF NATCHEZ AND VIDALIA AND NEW ORLEANS, MOUTH OF RED RIVER AND RECTIFICATION OF RED AND ATCHAFALAYA RIVERS, 484 MILES.

No work has been done on the harbors of Natchez and Vidalia since the date of the last report for want of funds.

The general plan recommended by the officer in charge in former reports contemplated protection of caving bends by means of submerged sloping spurs placed at intervals to be determined as work progressed, but assumed at 1,000 feet in preliminary estimate of cost, which was placed at $600,000.

A levee to prevent overflow of the neck between Giles' and Cowpen's bends was proposed at an additional cost of $100,000.

An estimate for mattress work and revetment instead of the method by spurs amounted to $1,040,000.

Work on the protection of that part of New Orleans Harbor known as Gôuldsboro Bend by means of submerged spurs was suspended in November for want of funds. Two spurs were finished and one about half built. Nearly all the material, except brush, is on hand for completing the six spurs proposed for the protection of this bend. The slope of the spurs begins at low water, and will be varied as may be deemed advisable.

The effect of those now in place cannot be determined until low water.

The cost of the first spurs was about $12,500 each, but new work of this kind is expected to be considerably less.

The revised estimate of the officer in charge for the completion of work in New Orleans Harbor on this plan is $654,400.

Work in Red River has been limited to keeping the channel open to navigation between the Mississippi and the Atchafalaya by means of tug-propellors and scrapers. This was not successful, except at a point near the Atchafalaya, where a short bar existed with deep water above. Temporary spurs of willow brush were tried along one reach, and a scraper suspended from the bow of a stern-wheel boat was used at other places.

The present value of the plant used in this district is estimated at about $58,000.

The expenditures during the time covered by this report were about $177,000, the balance available July 1 being about $16,000. For details reference may be had to the reports of Major Stickney and Assistants Douglas, Wilson, and Price, Appendices K and K 1, 2, 3, 4, and 5.

LEVEES.

Second district.—No work was done on levees of the Yazoo Front. For the repair of Long Lake Levee, Saint Frances Front, $15,000 were allotted, provided the district officer should find repairs necessary for its safety, the levee from Helena to the end of Long Lake to be repaired and completed before November 1, 1884, to a grade 2 feet above the flood of 1882.

The conditions were complied with, and the work, amounting to about 60,000 cubic yards of embankment, was put under contract and finished in March, 1885. Work was commenced at the lower end, where there were a number of large gaps, the people living behind the upper portion being looked to for the repair of that part.

Third district.—Work consisted in closing gaps in the levees on Yazoo and Tensas fronts, and comprised about 570,000 cubic yards of embankment. The work was put under contract in October, 1884, and all completed by April, 1885.

Fourth district.—Since the last report work has continued on Atchafalaya and Tensas fronts, chiefly the latter. About 9 miles of levees have been built or repaired, closing 40 gaps, and requiring over 300,000 cubic yards of embankment. The intervals remaining to be closed in this district aggregate about 32 miles.

The existing levees are now in fair condition, but are somewhat deficient in height.

For details reference may be made to the reports of the several district offices, Appendices H, I, and K.

PLAN AND METHODS OF IMPROVEMENT DISCUSSED.

The Mississippi River Commission, constituted under an act of Congress approved June 28, 1879, was required, in addition to completing the surveys then in progress and making such additional ones on the Mississippi River and tributaries as might be deemed necessary, to mature such plan or plans as will correct, permanently locate, and deepen the channel and protect the banks of the Mississippi River, improve and give safety and ease to the navigation thereof, prevent destructive floods, and promote and facilitate commerce and the postal service, and with such plans to prepare and submit estimates of the cost of executing the work.

It was also required under the law to report specifically upon the practicability, feasibility, and probable cost of the plans known as the jetty system, the levee system, and the outlet system; also to submit plans and estimates of cost of such immediate works as, in the judgment of the Commission, may constitute a part of the general system of works contemplated.

The first report of the Commission, dated February 17, 1880, discussed the jetty system, the levee system, and the outlet system, and recommended a plan of improvement which contemplates the concentration of the waters of the river as the principal agent in securing the needed improvement, and, briefly stated, the general and well-known principles on which the opinions of the Commission were based.

The outlet system, by which a portion of the flood waters of the river would be drawn off and conveyed through shorter routes to the Gulf, being one of diffusion and waste, and having very little in the way of either theory, experience or observation to recommend it, was unanimously rejected by the Commission for reasons set forth in the report.

The levee system and the degree to which levees might prudently be relied on as auxiliaries to a plan of improvement based on the concentration of the river waters was carefully considered. It was the opinion of a majority of the Commission that in time of bank overflow "levees exert a direct action in deepening the channel and enlarging the bed of the river"; that "they are regarded as a desirable though not a necessary adjunct in the general system of improvement submitted"; that "they are, upon a large portion of the river, essential to prevent destruction of life and property by overflow;" that "they give safety and ease to navigation, and promote and facilitate commerce and trade by establishing banks or landing places above the reach of floods, upon which produce can be placed while awaiting shipment, and where steam-

boats and other river craft can land in times of high water"; that "the closure of crevasses will accomplish the removal of shoals caused by them"; and that "it is believed that the repair and maintenance of the extensive lines already existing will hasten the work of channel improvement through the increased scour and depth of river-bed which they would produce during the high-river stages." A rough estimate of the cost of closing the breaks in the then existing levees was submitted with the first report.

The plan of improvement recommended was discussed at some length in general terms, beginning with the general statement that "the bad navigation of the river is produced by the caving and erosion of its banks, and the excessive widths and the bars and shoals resulting directly therefrom." Further on the report said: "It would seem, therefore, that the plan of improvement must comprise as its essential features the contraction of the water-way of the river to a comparatively uniform width, and the protection of caving banks"; and, again, "wherever necessary, the new bank must be protected by a mattress revetment, or some equivalent device"; and, again, "as a general rule, the channel should be fixed and maintained in its present location."

In the Commission's third report, dated November 25, 1881, it was stated, without dissent or qualification from any member, that "the bank revetments are intended not only to stop the constant and in some localities very rapid enlargement produced by erosion and caving of bends, but in addition thereto to check the growth of bars and shoals below by accretions supplied directly therefrom."

The plan submitted by the Board of Engineers on the improvement of the low-water navigation of the river below Cairo, in their report of January 25, 1879 (House Ex. Doc. No. 41, Forty fifth Congress, third session), in which they recommended "that the improvement be effected by narrowing the shoal and wide portions of the low-water river to about 3,500 feet, and by protecting caving banks where necessary," was unanimously adopted by the Commission for the initial works, and estimates and plans were given for "works of channel contraction and bank protection" on six reaches of bad navigation below Cairo, of an aggregate length of about 200 miles. In the report the cost of "works for contracting the channel" and "works for protecting the banks" was lumped together. The minutes of the proceedings of the Commission show, however, that a detailed estimate for each of the six reaches was prepared by a committee, presented to the Commission, and discussed and adopted without recorded dissent, all the members being present. In that estimate the works for bank protection on the six reaches were computed to cost four and half times as much as the works for channel contraction. On the Plum Point and Lake Providence reaches, the only portions of the river below Cairo on which works for the improvement of the channel have been undertaken, the works of bank revetment were estimated to cost nearly four and a half times as much as the contraction works.

The plan, therefore, contemplates the closing of outlets, both low-river outlets and crevasses; the contraction of the water-way of the river where the widths are excessive and the navigation bad; and the maintenance of the banks. In the execution of the plan thus briefly outlined, and in strict accordance with its original intent, and for no other object or purpose, the money appropriated by Congress has been expended.

The total cost of works of bank revetment and channel contraction

actually executed by the Commission between Cairo and Vicksburg, from the time it assumed charge to June 30, 1885, has been as follows:

Works for "protecting the banks"	$2,240,000
Works for "contracting the channel"	2,500,000

This statement includes the first cost of plant, less its present value, and includes also the cost of its maintenance to June 30, 1885. It also includes the cost of all work done in the Plum Point and Lake Providence reaches; also the cost of the special work put in for the protection of Memphis and Vicksburg harbors, all of which was bank revetment. The works of bank protection, or bank revetment, have, therefore, cost a little *less* than the works for channel contraction, instead of about four and a half times as much which was the original and unanimous estimate of the Commission.

A very considerable portion of the sum expended for bank revetment was designed to give protection to certain sites and harbors—Memphis, Vicksburg, and others. These harbors were given in charge of the Commission at a later period, and some of them required special and prompt treatment. If Delta Point had not been held by revetting its banks with mattresses at considerable cost, the city of Vicksburg would long before now have been practically an inland town, entirely cut off from the river. At Memphis great values were also put in jeopardy by a rapidly caving bank, which threatened to carry off a portion of the city. Bank revetment, as offering the only possible means of arresting the danger, was successfully applied in this case, although a portion of the work first put down was carried away, the loss of work put in by the Commission on both sides of the river amounting to 17¾ per cent. of its cost.

It has been claimed that the caving of banks should be arrested by works of channel contraction at the wide places above, and much unwarranted stress seems to have been laid upon a hypothetical discussion introduced into the first report of the Commission, where it is stated theoretically that "uniform depth joined to uniform width—that is to say, uniformity of effective cross section—implies uniform velocity, and this means that there will be no violent eddies or cross-currents, and no great and sudden fluctuations in the silt-transporting power of the current." But it is nowhere asserted in that report, nor is it believed by the Commission, that uniform depth, or any very near approach to it, is practically attainable upon the Mississippi River, or upon any large silt-bearing stream flowing through an alluvial bed and having a difference of 45 to 50 feet between its high and low water stages. In its low stage the obstructed portions of the river present a series of shallow crossings or bars, where the width is excessive and upon which there is frequently only about 6 to 10 feet depth of water, alternating with concave bends, where there are depths of 80 feet, and in some places of 90 to 95 feet and upwards. The scour induced by works of improvement at the wide places will doubtless deepen the channel across the bars to 15 or 20 feet, leaving the depths in the bends substantially unchanged, so that the full measure of approach to uniform depth attained by these results consists in this, that where there formerly existed, as between the deep bends and the shallow bars, a difference ranging from 70 to 90 feet in depth, there now exists, after the improvement, a difference of 60 to 80 feet or more. This represents an amelioration of former conditions, which, although sufficient for purposes of navigation, is evidently too small to affect in any considerable degree, or perhaps in any sensible degree, the cross-currents, eddies,

and fluctuations of velocity resulting from constantly varying depths. It would seem, therefore, that stability of banks, as the result of such uniformity of depth as can be secured by works of contraction, is practically unattainable. For this reason the plan of improvement contemplated a liberal use of bank revetment, roughly estimated to cost more than four times as much as the corresponding works of channel contraction.

It may be stated that it is not the intention nor has it been the practice of the Commission to protect a bank by revetment merely because it is caving. Other considerations must govern this question. But where an imminent danger threatens the immediate destruction of interests of great value—as, for example, where a caving bend is about to take in flank and carry away costly works of improvement or produce a disastrous cut-off, or where a city's river front is to be maintained, as at Vicksburg, or a portion of the city itself to be protected against undermining, as at Memphis—then it is believed to be imperative that the local remedy of holding the banks intact by a mattress revetment or other equivalent device should be adopted.

For a somewhat extended discussion of the phenomena of velocity, sediment transportation, and bank erosion, and the mutual relations among them, with pertinent tables and other data, reference is made to a paper by Commissioner B. M. Harrod, hereto annexed as Appendix B.

The money percentage of damage and loss in works constructed under the direction of the Commission from the time of its organization to June 30, 1885, between Cairo and New Orleans, is about as follows, the figures being above rather than below the exact percentage:

	Per cent. of cost.
Damage to works of channel contraction	22
Damage to works of bank protection	26
Aggregate damage to both classes of work	24

The foregoing includes the cost of maintenance of plant, and also its original cost less its present value. The varying methods of doing work, the frequent interchange of labor and materials between different points, and the difficulty of maintaining a well-arranged system of recording losses have rendered great precision unattainable. As a matter of precaution, outside figures are given.

It is in view of serious misapprehensions touching the original plan and recommendations of the Commission which have come to its notice, that it has been thought proper to make this somewhat extended reference to the place which the work of bank protection had in that plan, and to the amount, cost, and efficiency of the work of that kind which has been done.

THE ATCHAFALAYA OUTLET.

The apprehension which has prevailed to some extent that the Mississippi River may at any time, and probably will at an early day if left to itself, suddenly break through into the Atchafalaya, and thereafter make that stream its principal route to the Gulf, has never been shared by the Commission in the sense that the danger is imminent and not subject to easy control. There has been no enlargement of Lower Old River between the Mississippi and the head of the Atchafalaya, and no apparent tendency to enlargement. On the contrary, more or less dredging has been necessary every year to keep the passage open for the class of steamers navigating those waters, and even dredging failed to maintain the channel during the low-water stage of 1883, and all

steamboating on that route was suspended for several weeks. At the close of the fiscal year ending June 30, 1885, considerable shoaling was reported by the engineer officer in charge. The Commission has not failed, however, to recognize the fact that there is danger that in the event of a prolonged concurrence of high water in the Mississippi and low water in the Red, the existing outlet might be gradually enlarged to a capacity sufficient to discharge a large portion of the main stream, thus adding to the cost of any plan of works or method of treatment that might finally be adopted for that locality, whether designed to close it as an outlet or to convert it into a tributary.

In its last report, dated December 19, 1884, the Commission submitted a "plan for the rectification of the Red and Atchafalaya rivers by preventing further enlargement of the latter stream and restricting its outlet capacity." The plan comprised a series of six low dams in the Atchafalaya, to be subsequently connected with high levees across the head of the Atchafalaya Basin. A low-water dam to be placed in Lower Old River, between the Atchafalaya and the head of Turnbull's Island, was also suggested, having its crest 10 feet higher than the obstructions in Upper Old River, in order to deflect the Red, when below that level through the last-named channel.

The present recommendation is restricted to the low dams in the Atchafalaya, which, in the judgment of the Commission, should be begun by laying at least the sill-courses for all of them as soon as the stage of water will permit after funds shall have been provided for that purpose. Any modification of the details of the plan which may seem to be desirable will of course be made. The rapidity with which the dams shall be raised to greater height will be made the subject of careful study. All questions connected with the adjacent high-grade levees on either side, and with the low-water dam in Lower Old River above the Atchafalaya, will be held in abeyance for the present and made the subject of further recommendations.

VICKSBURG HARBOR.

It is desirable that a moderate portion of the first appropriation that shall become applicable to that purpose shall be expended upon the initial works of a plan having for its object the gradual restoration of the harbor of Vicksburg to or in the direction of its former condition, in such measure at least as shall give a portion of the city a water front at the low-river stage. This will be attempted by such works of contraction and deflection, located at suitable points above as shall ultimately effect a diversion of the main body of the stream to the Vicksburg side and a recession of the shore-line above the city, by the usual process of erosion and caving. An early effect will be to relieve the pressure, and therefore put a stop to expenditures at Delta Point. If the restoration of a navigable low river front to a portion of the city of Vicksburg, at a reasonable cost, is practicable, it will require several years for its final consummation in the manner proposed.

LEGISLATION.

The Commission renew the recommendation heretofore made that provision be made by law for the appropriation by the United States, through proceedings in the Federal court, of land and material needed in the work.

On this point reference is made to the suggestions of the report for 1883, without repeating them here.

The attention of Congress is further invited to the losses to assistant engineers mentioned in the secretary's report, Appendix C, of personal property, such as clothing, books, &c., incurred by the sinking of a survey-boat while being towed from one locality to another. These losses falling upon persons dependent upon their salaries are of much importance to them, and being incident to the service upon which they were engaged, and entirely beyond their control, reimbursement would be just and proper.

FINANCIAL STATEMENT.

Appropriation for salaries and expenses Mississippi River Commission, act of July 7, 1884.

Appropriated by act of July 7, 1884	$75,000 00
Balance on hand December 1, 1884	59,355 74
Expended from December 1, 1884, to June 30, 1885	36,634 50
Balance on hand July 1, 1885	22,721 24

Appropriation for surveys of Mississippi River, act of July 5, 1884.

Amount appropriated	$75,000 00
Balance on hand December 1, 1884	49,463 28
Expended from December 1, 1884, to June 30, 1885	33,314 71
Balance on hand July 1, 1885	16,148 57

Appropriation for Improving Mississippi River, acts March 3, 1881, August 2, 1882, and January 19 and July 5, 1884.

Total available October 1, 1884, for Improving Mississippi River		$2,031,753 91
Reverted to Treasury	$123 42	
Transferred to snag-boat service	5,000 00	
		5,123 42
Balance		2,026,630 49
Received from sale of fuel		179 57
Total		2,026,810 06
Expended		1,636,832 01
Balance available July 1, 1885, to meet liabilities and to carry on work under the Mississippi River Commission		389,978 05

The estimates of funds for fiscal year 1886, which were transmitted to the honorable the Secretary of War on July 25, 1884, are here repeated:

ESTIMATE OF FUNDS FOR THE MISSISSIPPI RIVER COMMISSION FOR THE FISCAL YEAR ENDING JUNE 30, 1887.

River and harbor bill.

For continuation of surveys of the Mississippi River between the Head of the Passes, near its mouth, and its headwaters, now in progress; to make additional surveys and examinations of said river and its tributaries; to make such additional examinations and investigations, topographical, hydrographical, hydrometrical, as are necessary for maturing a plan for the permanent improvement of the entire river	$100,000

Sundry civil bill.

For salaries and traveling expenses of the Mississippi River Commission, and for salaries and traveling expenses of assistant engineers under them, and for office expenses and contingencies	$100,000

The following estimate of funds for works of improvement for the fiscal year ending June 30, 1887, are submitted:

ESTIMATES OF FUNDS FOR THE IMPROVEMENT OF THE MISSISSIPPI RIVER FOR THE FISCAL YEAR ENDING JUNE 30, 1887.

For continuing the improvement of the Mississippi River from Des Moines Rapids to the mouth of the Illinois River	$500,000
For continuing the improvement of the Mississippi River from the mouth of the Illinois River to Cairo, Ill	1,000,000
For continuing the improvement of the Mississippi River from Cairo, Ill., to the Head of the Passes, including the improvement of the Red River at and below the head of the Atchafalaya	5,000,000

The names of a large number of harbors were inserted in the river and harbor bill, with a view to their improvement; but as the amount appropriated was far short of the estimates of the Commission, they did not feel justified in taking up this work except at Memphis, where the act specified the amount to be expended, and at Vicksburg, where repairs were needed to work already done. The Commission have, however, prepared the following separate estimates for such work at these places as seems necessary to accomplish the objects proposed, and these estimates are submitted to Congress for such action as they may deem proper, it being the desire of the Commission, if Congress decides that any or all of this work be undertaken, that they will specify the localities and the amount to be expended at each.

For improvement of the following harbors:

Columbus, Ky	$80,000
Hickman, Ky	270,000
Memphis, Tenn	75,000
Greenville, Miss	186,000
Vicksburg, Miss	20,000
Natchez, Miss	700,000
New Orleans, La	683,600
Total	2,014,600

Q. A. GILLMORE,
Colonel Engineers, Bvt. Maj. Gen., U. S. A.,
President Mississippi River Commission.
CHAS. R. SUTER,
Major of Engineers, U. .S.A
HENRY MITCHELL,
Coast and Geodetic Survey.
B. M. HARROD.
R. S. TAYLOR.
S. W. FERGUSON.

To the Hon. the SECRETARY OF WAR.
(Through the Chief of Engineers.)

While I generally concur in what is said in the foregoing report, I wish to add a few words by way of enlargement.

The cost of improving the Mississippi River in the manner and to the extent contemplated will doubtless considerably exceed the estimate formerly submitted by the Commission. For this there are two reasons principally: First, that it has been found necessary to make use of stronger and firmer, and therefore more expensive, methods of construction than those upon which, from a want of experimental knowledge, that estimate of cost was based; and, second, that the percentage of loss from floods has exceeded what was formerly thought to

be a fair allowance for this contingency. Much of this loss, however, would have been spared had the stronger methods of construction been resorted to at an earlier day, and future loss from this cause may therefore in some measure be avoided. In other respects, also, the experience gained in the application of new and untried devices cannot fail to tend in the direction of economy.

There seems to be no just ground for apprehension that the ultimate cost of this improvement will be inordinately great, or will exceed what the Government will be fully justified in expending upon a great national work, in the success of which so large and so varied interests are involved. In order, however, that the increased depths already secured upon two reaches of bad navigation may be utilized or made of some practical value, the improvement should be extended up-stream and down. Indeed, it cannot be said that the navigation has received any practical benefit whatever so long as the improvements are restricted to localities hemmed in by bad river above and below. It might be better, were no middle course left open, to spread each appropriation judiciously over all the six reaches of bad navigation selected for improvement below Cairo, adding a little each year, if practicable, to the available depths on the worst bars, than to confine the work to the Plum Point and Lake Providence reaches, as heretofore, even if the low river navigation of these two localities should be rapidly deepened to 20 feet, and the feasibility of the Commission's plan thereby fully demonstrated. The objective point is the improvement of the river, and not the vindication of the agents employed on the work, except as means to an end.

With regard to the estimates submitted, the Commission does not recommend that the sum of $2,014,600 should be appropriated for the seven harbors named, viz, Columbus, Hickman, Memphis, Greenville, Vicksburg, Natchez, and New Orleans. That sum is named as the aggregate cost of works of protection at those localities, as set forth in the last annual report of the Commission, bearing date December 19, 1884. In that list the sum of $20,000 set down for Vicksburg was intended exclusively for the maintenance of the Delta Point revetment.

In the report now submitted a special method of treatment for Vicksburg Harbor is described, and I recommend that the sum of $50,000 be set apart by Congress for beginning this work.

With regard to the conditions existing at the Red and Atchafalaya rivers, the work to be done there will, or should, have for its object the gradual contraction, and perhaps, finally, the complete closure, of the latter as an outlet of the Mississippi. Whether the treatment should be carried further than this, to the extent of making the Red River a tributary of the Mississippi, by the construction of a high dam across the head of the Atchafalaya River and basins, thus cutting off the latter stream from the navigation of the Red and Mississippi rivers, is a question involving considerations of very great moment. Fortunately its determination at the present time is not imperative, as the works necessary for its accomplishment naturally follow in order of time, those which may be built for simply contracting the outlet or preventing its enlargement.

By the principles enunciated as the basis of its plan of improvement the Commission is distinctly committed to the idea of closing all outlets as part of that plan, both low-river outlets and breaks in the levees, and it has consistently opposed the fallacy known as the "outlet system," because it stands in sharp antagonism to those principles and to all the fundamental laws of hydraulics. When the Atchafalaya shall cease to be

an outlet, the discharge of the Mississippi below the mouth of Red River will be increased about 40 to 50 per cent. by the addition of the volume now abstracted by the outlet. How long a time must necessarily elapse before the river, by a gradual enlargement of its bed, will be able to retain within the existing levees and safely carry off this increased volume, is largely a matter of conjecture. That it would do so in time will doubtless be very generally conceded by engineers who are familiar with the character of the deposits which have to be scoured away. Mr. Eads estimates that six years should be allowed for completely closing the head of the Atchafalaya Basin by such high works as will divert all the Red River flow into the Mississippi. While I am not prepared to say that this interval of time would not suffice, it would certainly be prudent to make it longer; for there might be an uninterrupted succession of moderate floods for four or five years, which would not overflow the banks even with the increasing additions due to the closure works in progress. If there should then occur a large flood when the works were nearly finished, the bed of the river would not be in condition to carry it off, and very disastrous consequences might ensue, more especially if both the Mississippi and the Red were in flood at the same time. But whatever interval of time may be allowed for the construction of the closing works, and the gradual enlargement of the river-bed, the levees below Red River should be carefully maintained during that time to their full height, strengthened wherever weak, and all breaks occurring therein promptly closed. As there are no portions of the river where levees sustain relations to the general plan of improvement more important than those which obtain in these lower reaches, so there are none where their importance is more likely to be underestimated or even entirely overlooked, for the reason that, the lower-river channel being at all times sufficiently deep for purposes of navigation, levees do not suggest themselves at all as a means of improvement below Red River. The essence of the whole matter is apt to be lost sight of, that they are required below for the benefit of the river above, and that they are valuable in proportion as they help to enlarge the river bed, facilitate the discharge of the floods, lower the flood heights, lessen the difference between high and low river, and thereby ameliorate and simplify all the difficulties of improvement. Indeed, were it necessary to omit the maintenance of levees, as an auxiliary means, on any portion of the stream, they might better be omitted above than below Red River. Were it possible to enlarge the bed of the river to a capacity that would be sufficient to carry off the flood-waters without any rise above the tide-level as far up as Red River, which would be practically extending the Gulf more than 300 miles up-stream, there would then be no greater difference between high and low river at that point than that due to the tidal oscillations, while for fully 200 miles higher up the largest floods would doubtless be retained within the natural bed. Works of improvement below Red River, of whatever character, are valuable as such only so far as they tend to the development of these conditions—that is, only so far as they aid in securing an enlarged local water-way. The general benefits to which reference has been made will be certain to follow in due proportion.

Respectfully submitted.

Q. A. GILLMORE,
Colonel Engineers, Brevet Maj. Gen., U. S. A.,
President Mississippi River Commission.

The Hon. the SECRETARY OF WAR.

(1) I fully concur in the opinion that any attempt to improve the navigation of the Lower Mississippi by contraction works alone, without the extensive use of bank protection, would be a failure. I think, even if it were possible in that way temporarily to improve the river, it would be only temporarily, since the river, still free to cave in its bends, would recede from those works unless the bends were held by protection-works, and would thus return to its present bad condition.

Not believing that contraction works alone can improve the navigable depth of the river, neither do I believe that revetment works alone can do it, and I am not in favor of either class of works, except in proper connection with the other. The Mississippi is like other rivers, differing only in size, and the general plans for improving rivers in alluvial bottoms, followed for many years in Europe and tested by experience, must be followed here—namely, contraction works, to secure increased depths where needed, and protection works in caving bends, to prevent the river from abandoning or destroying the contraction works, either during their construction or after their completion.

(2) I have little hope that the Mississippi can be forced at any justifiable cost far enough up along the Vicksburg front, which it has abandoned, to be of much use to that city. As there will be no funds available for about a year, the decision as to action should be based on conditions then existing.

(3) The Commission submits an estimate for an appropriation of $5,000,000 below Cairo. I am not prepared to recommend to Congress the beginning of work on any new reaches below Cairo until the final cost of the plan of the Commission for the improvement of the Plum Point and Lake Providence reaches is approximately known. At present no reliable estimate can be made, but the cost is already great. The final cost may be so great as to render a general improvement of the river inadvisable. Until this question is settled, work should not be begun on a great scale.

A million of dollars for the Plum Point Reach, as much for the Lake Providence Reach, half a million for the Memphis Reach and the sills in the Atchafalaya, is ample for the prosecution of these works in the coming fiscal year.

C. B. COMSTOCK,
Lieut. Col. of Engineers, Bvt. Brig. Gen.

NEW YORK, *July* 3, 1885.

Hon. WM. C. ENDICOTT,
Secretary of War.
(Through the Chief of Engineers, U. S. A.)

STATEMENT OF APPROPRIATIONS ALLOTTED AND EXPENDED FOR WORKS OF IMPROVEMENT UNDER THE MISSISSIPPI RIVER COMMISSION.

Act of March 3, 1881	$1,000,000 00
Act of August 2, 1882	4,123,000 00
Act of January 19, 1884	1,000,000 00
Act of July 5, 1884, less $5,000 transferred to snag-boat service	2,065,000 00
Total	$8,188,000 00
Balances from former appropriations for works below Cairo, July 1, 1882, less $123.42 reverted to the Treasury	272,504 98

Balances from former appropriations for works above Cairo, July 1, 1884	$22,632.53
For sale of fuel and loss of property	411 07
Total	$8,483,548 56

Expended to June 30, 1885:	
Des Moines Rapids to Illinois River	$120,949 22
Illinois River to Ohio River	389,339 56
Protection of easterly bank of Mississippi River near Cairo	27,839 99
New Madrid Reach	210,364 74
Plum Point Reach	2,379,019 12
Memphis Reach	477,073 04
Memphis Harbor	198,580 97
Lake Providence Reach	2,240,285 73
Vicksburg Harbor, dredging	61,812 12
Vicksburg Harbor, Delta Point	115,573 71
Survey of Helena Reach	8,000 00
Survey of Saint Francis Front, first district	4,873 11
Survey of Saint Francis Front, second district	4,000 00
Survey of unleveed fronts, third district	1,000 00
Survey of unleveed fronts, fourth district	1,000 00
Survey of Cubitt's Gap	137 14
Survey of Choctaw Bend	2,679 86
Observations at Carrollton	3,000 00
Closing Bonnet Carré crevasse	15,000 00
Levees.	
Second district:	
Yazoo Front	$80,950 00
Long Lake	15,000 00
Third district:	
Opossum Fork	25,000 00
Yazoo Front	364,875 45
Tensas Front	411,107 74
Fourth district:	
Atchafalaya Front	133,503 93
Tensas Front	548,258 24
Mouth of Red River	98,386 32
Natchez and Vidalia harbors	6,626 09
New Orleans Harbor	149,334 43
Total	$8,093,570 51
Balance July 1, 1885	$389,978 05

Respectfully submitted.

J. H. WILLARD,
Captain of Engineers,
Secretary Committee on Construction, Mississippi River Commission.

LIST OF APPENDICES ACCOMPANYING THE FOREGOING REPORT.

APPENDICES.

APPENDIX A.

PAPER BY GENERAL COMSTOCK ON EFFECT OF OVERFLOW IN DIMINISHING VELOCITY OF MISSISSIPPI RIVER, AND ON EFFECT OF LEVEES ALONG YAZOO FRONT ON FLOOD-HEIGHTS IN 1883.

To the Mississippi River Commission:

In the part of the last Annual Report of the Mississippi River Commission relating to levees and outlets certain views were expressed as to the effect of escape of Mississippi River water over the river-banks in diminishing the velocity of the main river, and on the effect of levees on the flood height in 1883 at Vicksburg, in which I did not concur.

There was then no time to discuss them, as it was necessary to forward the report at once. I have since examined these questions, and now state my reasons for disagreement with those views.

(1) First as to the theory that when escape over the Mississippi River banks begins, velocities in the main river are checked and deposits induced, and that the checking of velocity arises from this escape.

At some of the gauging stations of the Commission, when the river rises from about overflow stage to its maximum height, the velocities cease to increase with increased stage, and that part of the velocity curve becomes vertical.

The theory above mentioned has been advanced as an explanation of this peculiarity in the velocities.

The velocity curves should then be examined, to see if they support this theory.

The following lists give the names of places where we have a series of measures of the river's velocity both above and below the stage at which overflow begins. The number above the name gives the highest observed gauge-reading in the discharge observations, and the number under the name gives the stage at which overflow begins:

192.9
An examination of the velocity curves shows that at Prescott below the Saint
188.1
446.79 50.17 34.17 49.77 102.79 47.1 48.5
Croix, Winona, Saint Louis, Fulton, Paducah, Columbus, Helena, Red River Land-
443.4 49.7 32.0 41.0 95.0 41.0 44.5
ing, the velocities increase steadily to the highest gauge-reading without any important break in the regularity of the form of the curve.

34.42 88.20
In the curves for Grafton and Hannibal there are indications of a change in the
29.2 82.0
form of the curve, without its being very pronounced.

At Grafton the velocities are complicated by the nearness of the Illinois and Missouri rivers.

As the river rose from 32.2 feet on April 25, 1881, to 34.2 feet on May 5, the mean velocity fell from 4.6 feet to 3.9 feet. But water passing Leavenworth would reach the mouth of the Missouri River about five days later. Between April 20 and April 30 the Leavenworth gauge rose from 17.5 feet to 26.75 feet. When this rise reached the Missouri mouth, April 25, it produced a local rise there, backed the water up the Mississippi, and, diminishing the slopes, diminished the velocities at Grafton.

This Missouri rise showed itself at Saint Louis by a rise between April 25 and May 6 of 4.8 feet, the Grafton rise being but 2.0 feet.

At Hannibal there are no data for examining the question of slope.

17.98 38.59
At Clayton and Hays' Landing the change in the form of the curve is unmistakable.
11.0 34.4

(2) At Clayton the data are not very precise, but Lieutenant Leach reports (January 16, 1884) that existing information indicates that at the top of the flood the slope between Prairie du Chien and Clayton was about 20 per cent. less than at the gauge-readings when the curve changes its direction.

This decrease in slope would nearly balance the effect of increase from 14 feet to 18 feet in gauge-reading in increasing the velocity, and should make the velocity constant between the gauge-reading, as it is.

The fact that the slope of the main river is reduced, probably by a damming effect below, is enough to account for the change in form of velocity curve, without invoking the theory that escape over banks of itself at once reduces at the place of escape the velocity of the whole main river below its value before escape began.

In estimating the effect of change of slope on velocity for small changes in gauge-readings, the formula $V=C\sqrt{rs}$ is used, as it is known to give good results. V is the mean velocity, r the hydraulic mean radius, and s the fall in unit length.

(3) The second very marked change in the form of the velocity curve is at Hays' Landing.

From January 21, 1882, to March 20, 1882, the Hays' Landing gauge increased from 34.3 feet to its maximum, 38.6 feet. During this rise of 4.3 feet, the velocity curve was nearly vertical, or, rather, was inclined somewhat backward. On April 18 the gauge had fallen to 34.6 feet, and in this fall of 4.0 feet the velocity curve was also nearly vertical.

Again, on March 20, the gauge being 38.6 feet, the mean velocity was 5.4, while on June 6, the gauge being 34.1 feet, or 4.5 feet lower, the mean velocity was 6.3 feet, or 0.9 foot greater.

Were these peculiarities due to escape of water over bank and to the cessation of that escape?

The following table gives the data referred to, and also the fall on the same dates of the water surface between Lake Providence and Vicksburg:

Date.	Hays' Landing gauge.	Mean velocity.	Mean depth.	Fall, Lake Providence—Vicksburg.
	Feet.	*Feet.*	*Feet.*	*Feet.*
January 21, 1882	34.3	6.1	59.6	17.6
March 20, 1882	38.6	5.4	61.0	13.1
April 18, 1882*	34.6	5.3	60.8	14.0
June 6, 1882	34.1	6.3	62.1	17.2

* April 18, 19, 20, 21, the Hays' Landing gauge varied little, the mean of mean velocities on these days was 5.6 feet.

From this table it is seen that the mean depths varied but slightly, so that the cause of the changes in the mean velocities must be sought almost entirely in the changes of slope. From January 21 to March 20, while the river rose, the average slope from Lake Providence to Vicksburg diminished by 25 per cent. This should cause a diminution in mean velocity of 13 per cent. The actual diminution was 11 per cent. On March 20 and April 18 the mean depth was practically the same, although the river had fallen 4 feet. The slope increased 7 per cent., which should increase the velocity by 3 per cent. The velocity actually decreased by 2 per cent., but these quantities are so small that they are without certainty. The river fell 4 feet, but it also scoured 3.8 feet, so that the mean depth remained practically the same, as did the velocity. From March 20 to June 6, 1882, the mean depth increased by 2 per cent. and the slope by 23 per cent. These should give an increase of velocity of 12 per cent. The actual increase was 16 per cent.

It seems then that these chief irregularities in the Hays' Landing velocity (and hence discharge) curve are accounted for, as closely as could be expected, by the changes in slope in the main river, and hence, that there is no need to call in aid the theory that escape of water over the river banks makes the velocity less than before the escape began, and thus induces deposits.

(4) The cause of the great loss of slope between Lake Providence and Vicksburg, beginning prior to March 20, and nearly ending prior to June 6, is seen at once on examining the gauge curves. The great return flow from the Yazoo Swamp began to be of importance at Vicksburg about March 4, and was nearly over by May 19. During this time it was a great tributary, raising the river at Vicksburg several feet above the stage due to the water coming down the main river, and backing up the river as far as Lake Providence, thus diminishing the slope and the velocity.

(5) Finally, of the twelve stations considered, while at all the river went over its banks, but four show a stop in increase of velocity when the overflow stage is reached. Of these four the peculiarity at three is accounted for by the known slopes in the main river, and in the case of the fourth the data are not sufficient for discussion. If they were, the peculiarities would probably be accounted for in the same way.

It seems then that the cases considered give practically no support to the theory under consideration.

Whenever, as at Helena and Vicksburg, enormous quantities of water are added by

return flow to that flowing in the main river, there will be a local rise above the stage due to the main river alone. The effect of this local rise will be to diminish slopes and velocities for long distances above, the effect in the case of Vicksburg reaching to Lake Providence. This diminution in velocity does not occur when the escape begins, nor in consequence of the escape, but long after, when the return flow begins, and in consequence of that return flow. The return flow acts precisely like a tributary.

(6) The question whether, when escape over banks begins, the velocity in the main river is thereby reduced below what it was before escape began, may be examined in another way. The formula for mean velocity $V=C\sqrt{rs}$, shows us that in general terms the mean velocity can be reduced by diminution in mean depth, or in slope. But as the theory supposes rise in the river bed, to result from loss of velocity, the loss of velocity must precede diminution in depth, and hence can only arise from preceding diminution of slope. Even if, for instance, between Memphis and Arkansas City there were to be a mean rise in the river bed of 5 feet, as the mean depth of the river at flood is something like 50 feet, this diminution in r, in the formula, would only diminish the mean velocity by 5 per cent., a quantity that is less than the possible error in a good gauging.

Hence, immediately after escape begins, if there is any marked diminution in the velocity of the main river, it must inevitably be accompanied by a marked diminution in the slope of that part of the river where the escape takes place; if no such diminution in slope occurs, it is certain that no marked diminution in velocity in the main river will occur.

In the flood of 1882, the measured escape into the Yazoo bottom, between Memphis and Arkansas City, was 780,000 cubic feet. If there is any truth in the theory under consideration, this enormous escape should show itself in a large diminution in the velocities and in the average slope of the river between the two places, in the interval of time between the beginning of the escape and the date on which it reached its maximum amount. Escape began at Memphis on January 15, 1882, with Memphis gauge reading 29.5 feet. On February 28, 1882, the gauge at Arkansas City reached its maximum.

The following table gives the falls in the river surface between gauges on these dates:

Locality.	Fall on January 15, 1882.	Fall on February 28, 1882.
	Feet.	*Feet.*
Memphis to Helena	31.8	30.9
Helena to White River	31.6	30.5
White River to Arkansas City	13.8	13.8
Total fall	77.2	75.2

That is, the diminution in slope between these dates does not amount to 4 per cent. either for the whole or the partial distances. This diminution in slope would correspond to a diminution of mean velocity of less than 2 per cent., a quantity so small that accurate discharge-observations would probably fail to detect it. Moreover, between these dates, the return flow from the Saint Francis Swamp had begun, and had locally raised the river at Helena and below; without this disturbing element it is probable that the slope between Memphis and Helena would have increased instead of having slightly diminished.

It seems, then, that this method of examination also negatives the supposition of a sudden diminution in the velocity of he main river when overflow begins.

(7) *Did levees, built in 1882–'83, reduce flood heights at Vicksburg in 1883?*

In 1882 and 1883 the floods at Helena reached nearly the same heights, namely, 47.2 and 46.9 feet, while these floods at Vicksburg reached heights of 48.7 and 43.8 feet, or the second was about 5 feet lower. This reduction in flood-height at Vicksburg has been attributed to levees built in 1882–'83.

It does not seem necessary to go to the levees as a cause for a result which would have occurred without any change in them. The maximum flood at Vicksburg, in both years, was caused by the superposition of the Yazoo Swamp outflow on the water flowing in the river. In 1882 J. B. Johnson observed an escape into the Yazoo bottom of 780,000 cubic feet per second, and H. Stewart observed that of 1883 as 546,000 cubic feet per second.

The maximum return flow in any second was probably less at Vicksburg in 1883 than in 1882, but the return flows in the two years affected the Vicksburg gauge by about equal amounts.

Were these return flows superposed in the two years on equal discharges of the main river? Or was the discharge of the main river above the entrance of the Yazoo Swamp discharge very much less in 1883?

Helena is 293 miles above Vicksburg, and the water which follows the river passes in flood over this distance in about three days. If then, the Helena gauge be examined three days before a given date at Vicksburg, an idea can be formed as to the amount of water which, coming from Helena, is passing Vicksburg on that date.

In 1882 the maximum stage of 48.7 feet was reached at Vicksburg on March 20. The river stage at Helena three days before was 46.2 feet, and it was this 46.2 feet discharge plus that of Arkansas and White rivers plus the Yazoo Swamp return flow* which carried the Vicksburg gauge to 48.7 in 1882, on March 20. In 1883 the Vicksburg gauge reached its maximum, 43.8, on April 7. Three days before the Helena gauge read, on April 4, 1883, 32.7 feet, in place of 46.2 in 1882. It was this 32.7 feet discharge plus the Arkansas and White rivers plus the Yazoo Swamp discharge which gave the Vicksburg maximum of 43.8 in 1883, on April 7. 46.2 minus 32.7 is equal to 13.5 feet, and this difference in the Helena gauge in the two years ought to largely reduce the Vicksburg gauge in 1883. It and the probably smaller return flood reduced it 4.9 feet below 1882.

But while the Mississippi at Helena was carrying much less water in 1883 than in 1882, three days before the Vicksburg maximum, the Arkansas and White rivers were also adding less water to the Helena discharge. Allowing seven days for the water at Little Rock and at Jacksonport to reach Vicksburg, it may be said that in 1883, seven days before the Vicksburg maximum, the Little Rock and Jacksonport gauges read 10 feet and 9 feet, while in 1882 they read 16 feet and 22 feet.

In view of the far less flow past Helena at the time of the Vicksburg maximum in 1883 than in 1882, the Helena stages being 32.7 and 46.2, respectively, and in view of the smaller contribution of the White and Arkansas rivers, the theory that levees reduced flood height at Vicksburg in 1883 as compared with 1882 is not needed to account for the facts.

C. B. COMSTOCK,
Lieut. Col. of Engineers,
Brt. Brig. Gen., U. S. A.,
President Mississippi River Commission.

NEW YORK, *March* 15, 1884.

APPENDIX B.

PAPER BY COMMISSIONER B. M. HARROD, ON THE PROTECTION OF BANKS.

I desire to submit the following observations and opinions concerning the protection of banks as part of the plan of improvement of the river below the mouth of the Missouri.

Whenever the movement of current against a bank has sufficient force, either from mass, velocity, or angle of impact, the submerged part is scoured away and the superincumbent bank "caves." Therefore, this action largely occurs in deep and narrow bends, where the resistance of the banks must impress a curved motion on the flowing mass; in wide reaches at the lower ends of crossings; or at any other place where the location or direction of the channel subjects the bank to abnormal stress.

In this practical way is the caving of banks accounted for rather than by the theory that the charge of sediment always has or is seeking a fixed relation to the velocity, coupled with the dogma that the erosion of banks results from an undercharge of sediment in the passing water, and not from the friction or impingement of the current against them. From the theory here alluded to is drawn the conclusion that the uniformity of velocity caused by uniform section will so adjust the load of sediment that it cannot be increased, and therefore that the banks will not erode.

Of course the movement of water and the suspension of sediment stand as cause and effect and their relation is governed by law, but our knowledge thereof as concerning the Mississippi below the Missouri is still quite covered by the expressions used by the majority in the first report of the Commission:

"No fixed relation has been discovered between a volume of water and the sediment in it for any given observed velocity. The supply of earthy matter is very irregular, varying greatly, irrespective of changes of velocity, with fluctuations in the stage of river, the relative discharge of different tributaries, the seasons of the year, the conditions governing rainfalls, alternations of freezing and thawing, the kinds of crops cultivated in the vicinity, and other causes."

The observations conducted by the Commission have corroborated fully the authority on which this statement is made.

I here insert tabulated results of an examination of every extended series of sediment observations made between Cairo and the head of the passes. These are five in number, as follows: Carrollton, 1851–'52, Humphreys and Abbot; Columbus, 1858,

* Strictly this should be excess of return flow over escape below Helena. A number of corrections have been made in the original paper.—C. B. C., July, 1885.

umphreys and Abbot; Columbus, 1879, Maj. C. R. Suter; Fulton, 1879–'80, Mississippi River Commission; Carrollton, 1879–'80, Mississippi River Commission.

The tables show the volocities, graduated in half feet, and the observed quantities sediment during the several periods when each rate of velocity prevailed.

CARROLLTON, 1851–'52.

Velocity—feet per second.	Periods of observations.	Number of observations.	Extreme range of observations.	Mean grams of sediment in 600 grams water.
1.5 to 2.0	1st	13	104–282	.168
	2d	1		.092
2.0 to 2.5	1st	2	266–369	.317
	2d	2		.184
	3d	1		.192
2.5 to 3.0	1st	1		.414
	2d	1		.510
	3d	1		.097
3.0 to 3.5	1st	2	474–520	.497
	2d	1		.514
3.5 to 4.0	1st	1		.304
	2d	3	131–350	.207
	3d	1		.692
4.0 to 4.5	1st	1		.169
	2d	3	450–918	.636
	3d	1		.591
4.5 to 5.0	1st	5	197–276	.226
	2d	6	443–662	.557
5.0 to 5.5	1st	1		.614
5.5 to 6.0	1st	2	442–595	.518
	2d	2	241–271	.256
6.0 to 6.5	1st	1		.346

COLUMBUS, 1858.

Velocity—feet per second.	Periods of observations.	Number of observations.	Extreme range of observations.	Mean sediment Troy grains per cubic foot.
1.5 to 2.0		22	44–221	181
2.0 to 2.5	1st	8	155–420	233
	2d	8	125–258	188
	3d	1		354
2.5 to 3.0	1st	3	472–708	605
	2d	1		281
3.0 to 3.5	1st	5	422–598	535
	2d	1		502
3.5 to 4.0	1st	10	465–664	603
	2d	3	280–391	325
	3d	5	383–628	502
	4th	3	317–376	347
4.0 to 4.5	1st	2	605–641	623
	2d	2	406–738	572
	3d	2	140–266	203
	4th	3	354–487	421
4.5 to 5.0	1st	2	269–378	323
	2d	1		269
	3d	3	524–567	541
	4th	5	332–797	564
5.0 to 5.5	1st	1		346
	2d	1		280
	3d	1		635
5.5 to 6.0	1st	2	235–279	257
	2d	1		539
6.0 to 6.5	1st	1		288
	2d	1		490
6.5 to 7.0	1st	1		288
	2d	5	147–294	204
	3d	1		199
7.0 to 7.5	1st	4	211–307	264
	2d	2	470–538	504
	3d	1		278
	4th	2	235–382	308
	5th	1		155
7.5 to 8.0	1st	1		258
8.0 to 8.5	1st	1		355
	2d	4		323

COLUMBUS, 1879.

Velocity—feet per second.	Periods of observations.	Number of observations.	Extreme range of observations.	Grams per cubic foot.
2.0 to 2.5	1st	3	22 – 37	29
2.5 to 3.0	1st	17	24 – 65	41.4
	2d	4	27.5 – 30	28.6
3.0 to 3.5	1st	23	20 – 110.5	57.2
3.5 to 4.0	1st	3	5 – 6.5	5.5
	2d	2	146 – 146	146
4.0 to 4.5	1st	5	5 – 7	6
	2d	2	22 – 27	24.5
4.5 to 5.0	1st	1		34.5
	2d	5	27 – 55	37
5.0 to 5.5	1st	2	11 – 12	11.5
	2d	2	42 – 47.5	44.75

FULTON, 1879-'80.

Velocity—feet per second.	Periods of observations.	Number of observations.	Extreme range of observations.	Mean sediment m. gr. in 500 c. centimeters.
2.0 to 2.5	1st	11	265–420	330
	2d	14	295–500	301
2.5 to 3.0	1st	9	448–580	511
	2d	4	290–385	311
	3d	5	405–465	434
3.0 to 3.5	1st	4	230–470	311
	2d	[illegible]	505–820	647
	3d	9	410–040	524
3.5 to 4.0	1st	1		290
	2d	3	[illegible]	271
	3d	4	705–855	754
4.0 to 4.5	1st	3	210–220	215
	2d	[illegible]	230–440	336
	3d	4	265–310	281
	4th	12	435–640	538
	5th	2	860–700	825
4.5 to 5.0	1st	3	215–265	240
	2d	2		460
	3d	[illegible]	430–450	439
	4th	5	570–950	777
	5th	3	500–935	758
5.0 to 5.5	1st	1		390
	2d	2	890–890	385
	3d	3	850–945	908
5.5 to 6.0	1st	1		235
	2d	1		580
	3d	3	360–710	590
	4th	1		355
	5th	2	860–970	915
	6th	3	750–850	812
6.0 to 6.5	1st	1		335
	2d	1		200
	3d	6	215–395	317
	4th	1		380
	5th	1		275
	6th	5	985–1165	1062
	7th	1		840
6.5 to 7.0	1st	1		410
	2d	1		260
	3d	1		180
	4th	4		600
	5th	1		1066
7.0 to 7.5	1st	3	290–550	406
	2d	3	410–700	563
	3d	2	140–140	140
7.5 to 8.0	1st	1		325
	2d	2		145

CARROLLTON, 1879-'80.

Velocity—feet per second.	Periods of observations.	Number of observations.	Extreme range of observations.	Mean sediment in gr. in 500 c. centimeters.
1.5 to 2.0	1st	1		175
	2d	2	125–168	146
2.0 to 2.5	1st	3	245–375	313
	2d	3	190–190	190
2.5 to 3.0	1st	2	300–500	445
3.0 to 3.5	1st	1		400
	2d	1		323
	3d	1		470
3.5 to 4.0	1st	2	266–282	274
	2d	2	336–380	356
	3d	1		574
4.0 to 4.5	1st	1		670
	2d	1		230
	3d	2	506–536	521
4.5 to 5.0	1st	1		314
	2d	1		214
5.0 to 5.5	1st	1		536
	2d	1		218
5.5 to 6.0	1st	2	370–350	388

The extreme results of these observations can be condensed as follows:

CARROLLTON, 1851-'52.

Date.	Gauge.	Discharge, cubic feet per second.	Velocity, feet per second.	Proportions of sediment by weight.	Total pounds of sediment.
January 21	6.	482, 392	3.	[illegible]	25, 616
June (third week)	11. 0	779, 384	4. 40	[illegible]	74, 482
April 1	15. 25	1, 112, 559	5. 96	[illegible]	27, 924

COLUMBUS, 1858.

August 30	13.	267, 700	2. 55	[illegible]	27, 027
July 22	23. 7	500, 350	4. 64	[illegible]	67, [illegible]
June 28	38.	1, 150, [illegible]	7. 23	[illegible]	25, 018
June 14	39. 6	1, 318, 733	8. 04	[illegible]	60, 850

COLUMBUS, 1879.

July 2	23. 4	410, 000	3. 75	[illegible]	131, 825
April 5	33. 65	720, 000	5. 20	[illegible]	18, 079

FULTON, 1879-'80.

July 31	168. 25	340, 000	3. 5	[illegible]	34, 836
March 28	188.	1, 070, 000	7. 75	[illegible]	19, 367

CARROLLTON, 1879-'80.

August 19	2.	315, 000	2. 36	[illegible]	14, 769
August 9	4. 40	425, 000	2. 93	[illegible]	23, 809
May 19	13. 40	850, 000	5. 34	[illegible]	23, 047

These results, which cover all observations on the subject, clearly give no support to the statement that the charge of sediment in the Lower Mississippi is proportioned to the velocity, nor do they admit of explanation by the suggested effect of depth in modifying the relation between these two functions. There is, however, no obscurity in the cause of these apparent anomalies. The stage of the Missouri and other silt-bearing tributaries, in relation to that of the clear-water tributaries, is evidently the influence most largely controlling the amount found at any time in the river. High water from the Missouri is heavily charged with sediment even to the Gulf, while from the Ohio there is but little sediment, with equal or greater heights and velocities.

Under these conditions the law governing the relation between velocity and sediment is no further useful than was stated in the first report of the Commission:

"Any reduction of velocity, by lessening the sustaining and transporting power of water, and by arresting some of the heavier particles which the diminished current is unable to move along the bottom, will tend to cause a deposit of solid earthy matter and raise the bed of the stream."

But even if the adjustment of sediment to velocity is admitted, the caving of banks would still continue as the direct effect of the impact of the current. This is clearly shown by the results of comparative surveys below Cairo. There the demarkation between the muddy discharge from the Mississippi and the clear water from the Ohio while flowing side by side is sharply defined. It is frequently observable by the eye for a distance of twenty or thirty miles and by the sediment trap for a distance of two or three hundred miles. Yet the caving on the right bank washed by water more heavily charged with sediment exceeds that on the left bank, as is shown by the following table, constructed from comparative surveys by the Commission, covering a peroid of four years:

Length of river below Cairo.	Right bank.		Left bank.	
	Length of erosion.	Area annually eroded.	Length of erosion.	Area annually eroded.
	Feet.	*Sq. ft.*	*Feet.*	*Sq. ft.*
25 miles	35,000	2,345,000	20,000	1,740,[illegible]
50 miles	78,900	6,285,600	65,500	3,000,[illegible]
75 miles	110,200	8,639,100	75,500	5,720,[illegible]
110 miles	186,650	17,443,350	172,000	15,016,[illegible]
150 miles	288,350	26,892,150	260,800	27,062,[illegible]
200 miles	344,650	35,797,060	279,800	28,548,[illegible]
To Memphis	390,650	41,709,850	332,800	25,471,[illegible]

The conclusion is thus reached that the amount of sediment is not mainly controlled by the velocity nor the amount of caving by the degree of sediment saturation of the passing current.

The same conclusion is reached by any logical arrangement of all the observed facts.

By the terms of the theory of the development of an alluvial stream, its bed and banks are shaped and built by its own forces with a uniform section, in regimen with its other elements. The dimensions are adjusted to the slope and discharge, and the bed approximates such form as offers least resistance. The river, therefore, in its normal condition, realized the correction which is now proposed for its regularization. Then why has this ideal state been disturbed by caving, and why are artificial means now required to restore, or even maintain, a natural condition?

Assuming that the proposed correction had been applied, giving uniform width and velocity, and that in consequence caving was checked, we should then have less sediment by the amount thereof now contributed by caving banks and a velocity greater because relieved from the work of suspending and transporting that amount of sediment. Under these conditions why should not erosion be increased rather than diminished if the theory under discussion is true?

Again, uniformity of section affects only mean velocity. The extremes would still vary greatly after all the contraction necessary for navigation was accomplished. Along the bank, as it is concave or convex, the current would still flow with the same alternations of velocity as at present, and with the same differences of sediment predicated by the theory. The fill and scour of the bank would therefore continue.

From experience it is known that a deposit up to the height of the high-water bank cannot be induced by contraction works in less than four or five years; also, from experience and the terms of the theory, caving will not cease until the high-water contraction is complete. During the period of construction caving will continue,

and the line of the new shore, and the contraction works defining it, must be annually advanced at an equal rate. If they are not, by the time complete results are attained on the original line the river will have recovered the width that first made contraction necessary. If the line is thus annually advanced the cost of contraction will soon largely exceed that of bank protection.

Probably more than half the material contributed by caving is from the bank above the limit of erosion or the water surface. The weight and bulk increase in a greater ratio than the height. Therefore an undue proportion is contributed at low water and where the banks are high. For this reason an illustration taken from the river when the rise and fall is small, as at Fort Saint Philip, is unfair, particularly as it is known that the soil, as we proceed down the river, becomes less sandy and more tenacious.

If this theory were correct the greater caving would occur during the rise of the river, which is a period of increasing velocities. But it is well known that the reverse of this is true, and that caving is excessive during the falling river in a period of decreasing velocities.

While it is true that the caving is less below than above Red River it cannot be accounted for by greater uniformity of velocity. The great depth allows and the small width compels a general movement of the mass approximately parallel to the axis of the bed. Above Red River the immense bars lying athwart the channel and the great width of the bed directs the entire volume against the bank. This action is mainly developed during the falling and low stages, when the caving is observed to be the most extensive.

This theory can be here left as unproved by the facts and insufficient to account for the results.

To the caving of banks can be attributed, in great part, the deterioration of the river, both as a navigable channel and as a drainage line; and also the difficulties encountered in the improvement of either of these functions. In the first place, by caving, both the length and the high-water width of the river is increased. Although the deposit on the convex or growing side may be equal, in any given time, to the amount caved away from the opposite bank, yet these two masses of material are of such relatively different shapes that their opposite movements, one of accumulation and the other of waste, give as a net result an increased width of river. The material from the convex bank, precipitated into the swiftest current of the river, is promptly swept away. The opposite side of the bed, being higher, is less deeply submerged and by water less rich in sediment. Therefore, while the extension of the new deposit out into the channel may be as rapid as the recession of the opposite shore, its elevation to the normal bank height of the river is very gradual.

All exact observations confirm a conclusion which is sufficiently obvious from a general knowledge of the river. The most important of these are appended in tabulated form:

Locality.	Distances.	Time.	No. of widths.	Mean increase.	Per cent.	Authority.
	Miles.		*Feet.*	*Feet.*		
Cairo to New Orleans	963	1821 to 1874, 53 years.	319	1,813	.74	Poussin, U. S. Rec. Suter, U. S. Rec.
Cairo to New Orleans	963	1851 to 1874, 23 years.	219 319	1,219	.40	H. & A. Hyd. Miss. Suter, U. S. Rec.
Coles Creek to Tunica	100	1851 to 1883, 32 years.	11	334	.105	H. & A. Hyd. Miss. Miss. Riv. Com.
Baton Rouge to Donaldsonville.	52	1851 to 1883, 32 years.	68	149	.053	H. & A. Hyd. Miss. Miss. Riv. Com.
Point Houma to New Orleans.	75	1851 to 1875, 24 years.	40	66	.03	H. & A. Hyd. Miss. Maps U. S. C. & G. S.

The first instance probably gives an excessive result from the vagueness of the earlier authority. The two last are in parts of the river where changes are very much slower than above Red River; but the general movement is established. Instances of caving of 1,000 feet per year are not unknown:

As the width of the river increases its mean depth diminishes. Continued widening develops a very characteristic shape of bed, in which the deepest water is along both banks, and a middle ground or bar area at the intermediate node or reversion point between bends. The absence of defined channels across this bar area from one pool to another is the obstruction to low-water navigation. The development of channels through it is the result of the relative increase of local velocity by the reduction of area as the water falls at the bars. If these channels increase in number, as frequently occurs, they become tortuous, uncertain, and the navigable depth in each diminishes. The physics of this bar formation, characteristic of all natural

water-courses with yielding beds, is discussed by Major Suter (Report Chief Engineers, 1881, p. 1649), and by Professor Mitchell (Report Mississippi River Commission, 1882, Appendix S, p. 263), to which papers I beg leave to refer.

Two results of much importance in the improvement of navigation follow these conditions.

(1) As the shape of a bend changes by caving a new direction is constantly given to the maximum scouring effort of the river, by which a low-water channel or crossing is developed through the bar at the node below. Hence it is impossible to "permanently locate" this channel until the shore-line of the bend above is fixed. If contraction works are located at any time with reference to existing currents and channels, their continued usefulness depends upon the maintenance of the direction of these currents. Professor Mitchell says: "These bars are not permanent in position; on the contrary they are prone to shift as the bends become more acute, extend, or move downwards. Indeed, under the general rule that the bars form at the reversion point of curves, it is evident that their positions must vary as these curves vary, and that, the holding of the curves, by revetment or otherwise, is an essentially early step in the control of the river. It antedates logically the retrenchment which is to deepen the water at the bars."

(2) The continued change in the shape of a bend by caving and of the location of the crossing below, which marks the thread of movement of the stream, necessarily changes the direction in which the current enters the bend below. Hence, this is subjected to new and shifting attacks, and the ill effects of caving in an upper bend is transmitted downwards in turn from bend to bend. It is fair to infer that if the caving in any one bend were arrested the transmitted effect below would ultimate itself and cease. As it is, the increase of caving is in a compound rather than a simple ratio.

In the next place, from caving banks is derived a large part of the material of which bars are composed. If the results of the observations by the Commission on caving banks be prorated over the length of the river below Cairo, omitting any consideration of the part below Red River, for safety in estimating, and a mean depth of 100 feet be assumed for the caving, then the amount contributed from this source is about four times as great as the sediment discharge of the river as computed by Humphreys and Abbot.

The banks are, generally speaking, of sand and clay, seldom purely of either material, but mixed in different proportions, according to the conditions under which they were built. When they yield to the encroachment of the river, the finer and lighter portions readily float long distances with low velocities, and are mainly deposited in quiet water, under the shelter of willow points. The sediment from the Missouri floats so readily that at times, at a distance of 1,200 miles below its mouth, at medium and low stages, and correspondingly small velocities, not only the charge of sediment per unit of measure, but even the total bulk afloat is greater than at times of great flood from the Ohio, when the discharge and velocity are approximately doubled. But the more important part, both in quantity and function, the sand and fine gravel, sinks rapidly, forming a loose and movable bed, which is shaped into sand waves and bars by the forces of the river, constantly changing in direction and intensity. If it falls in a pool where the scouring power of the higher stages is concentrated, the next flood sweeps it down to the bars on the wider section below, where the current spreads and its transporting power abates. From this halting place, where the current becomes relatively greater as the lower stages are reached, it is scoured down into the comparatively still pool below. The range of elevation of these bars during the annual oscillation of the river frequently exceeds the depth found on them at low water. A high-water survey, reduced to low-water gauge-readings, would exhibit numerous dry bars extending entirely across the bed. The more important down-stream movement of sediment is, therefore, intermittent, and it can be understood that the same material may enter successively into the composition of each bar as it moves by semi-annual excursions toward the sea.

Besides these uses for bank revetment, which may be classed as conservative, I assign it another duty, in restoring that uniformity of section and velocity, which is of obvious importance in the regularization of rivers. The extreme variations of width now existing, with a tendency toward further increase, are not normal, but are exaggerated by caving. The physical history of the river is not one of growth from a narrow to a wide stream, but of the replacement of a much wider expansion of surface by a defined and limited water-way, of an estuary by a river. The bed still strives to conform its dimensions to the smallest section that will contain the volume flowing through it, and to a shape that will offer least resistance. The reversion of this process, as is now observed, marks the presence and control of abnormal influences. It is therefore just to expect that when the elongation of points and the growth of middle bars is resisted by the establishment of permanent banks, the material now used in their extension toward the retreating bank will be deposited over areas outside of the required bed limits so as to raise them up to bank level, and thus,

by narrowing the bed, restore more favorable conditions both for navigation and discharge.

As compared with contraction work by dikes or screens, I believe that bank protection, for any given length of river, is of not greater cost, while more rapid in construction; can be made more enduring, as less exposed to drift, ice, and the alternations of wetting and drying; and its ultimate effect in adjusting widths and sections will be equally certain and more permanent than dike-work. Besides this, while even from experience it is obvious that the necessity for the protection of caving banks is not obviated or reduced by dike-work, it may be justly expected, from reasons before given, that permanence of bank, and, consequently, of channel, will have effects that will to some extent reduce the amount of artificial contraction required. The obvious illustration of this is the exceedingly narrow and deep sections along the foot of bluffs at Columbus, Fulton, Randolph, Memphis, the old Vicksburg and Grand Gulf channels, and at the other points below. Acknowledging entirely the importance to navigation of an equalization of width, the prevention of caving is a certain, permanent, and economical way of securing it. I therefore recommend the completion of this part of the work from Saint Louis to Cairo, and its commencement at Cairo and extension down river, in bends where, in the judgment of the Commission, caving is rapid enough to be injurious to navigation by widening or preventing the permanent location of the channel or by increasing the supply of bar material. This general order of progress is proper, because the work secures itself from attack from above as it progresses, and is constantly exerting a conservative and beneficial influence through the reaches below. It may, however, at times be advisable to anticipate the general progress of the work where very disastrous caving is going on, and particularly where a cut-off or the destruction of a harbor or important contraction works is threatened. It must not be forgotten that if bank protection is continued as part of the plan of improvement the results of dike-work will become slower, and therefore more costly, since the supply of sediment which the latter is intended to arrest will be diminished by the extensive application of the former. To a certain extent choice must be made between the two methods. Without permanent banks contraction is impracticable. With permanent banks, the channel will be directly improved, and a certain amount of contraction will naturally result.

B. M. HARROD.

NEW ORLEANS, *February*, 1885.

APPENDIX C.

ANNUAL REPORT OF THE SECRETARY OF THE COMMISSION UPON THE WORK OF SURVEYS AND EXAMINATIONS.

OFFICE OF MISSISSIPPI RIVER COMMISSION,
2828 WASHINGTON AVENUE,
Saint Louis, *June* 18, 1885.

GENERAL: I have the honor to submit the following report of the work of the secretary's office and of surveys and examinations during the fiscal year ending June 30, 1885.

My duties as secretary only began upon March 3, when I relieved Capt. Smith S. Leach, Corps of Engineers, who had performed those duties from August, 1879, to that time.

The operations carried on under this office for the past year have been the inspection and repair of gauges on the main river below Saint Louis and on tributaries; the checking, compilation, and publication of gauge records; field work of topography and hydrography; the reduction and plotting of field notes, and the preparation, publication, and distribution of maps; the printing of tabulated data, gauge records, proceedings of the Commission and reports; observations for computing the discharge of the main river at six selected points below Cairo, and of the Atchafalaya near its head, and of Old River between the head of the Atchafalaya and the Mississippi; the reduction of the notes of these observations, and the computations therefrom; various local examinations made by the assistant with the steamer Patrol and in charge of inspection and repair of gauges and bulletins; tidal observations to determine the mean gulf level upon a gauge established near Biloxi, Miss.; the reduction and compilation of physical data of the Mississippi River and the Alluvial Valley; the classification and filing of the reports and records pertaining to the Commission; the disbursements of the funds appropriated for the expenses of the Commission, and for surveys under its direction, and the clerical work rendered necessary by these duties.

For purposes of organization and to systematize the labor, the office work, as was

noted and described in the last annual report of the secretary, is distributed and allotted to divisions, with assistants in charge of each.

The topographical division is in charge of Mr. J. A. Ockerson, assistant engineer, and there have been associated with him Assistants C. M. Winchell, C. W. Clark, Moses Greenwood, jr., O. W. Ferguson, O. A. Orrman, F. B. Maltby, and J. T. Desmond. Mr. Edward Molitor has been employed throughout the year in this department in drawing and preparing charts for publication and engraving sheets of titles, notes, and table of distances to accompany published series of maps.

The computing division is in charge of Mr. L. L. Wheeler, assistant engineer, and there have been attached to this division, either throughout the year or in the intervals between field duties, Assistants Kivas Tully, T. C. Thomas, L. C. Jones, J. W. Dorst, H. P. Ritter, G. W. Wood, and H. B. Wood.

The field work of topography performed was executed by Mr. C. M. Winchell, assistant engineer, having under his orders Assistants C. W. Clark, O. W. Ferguson, H. B. Wood, L. C. Jones, H. W. Kerr, F. B. Maltby, O. A. Orrman, Moses Greenwood, jr., G. H. French, and Recorders D. E. Perkins and Isaac Purcell.

The inspection and repair of gauges has remained in charge of Assistant John Ewens, and the parties making discharge observations were in charge of Assistants E. E. Haskell, G. W. Wood, A. H. Weber, J. W. Dorst, Homer P. Ritter, and M. K. Bowen.

FIELD WORK OF TOPOGRAPHY AND HYDROGRAPHY.

This consisted of the completion of topography below Cairo, with a line of levels, filling in the gap existing between the point near the Kentucky-Tennessee state line where work of the preceding season ended and Caruthersville, Mo., closing on the upper limit of Assistant L. L. Wheeler's work of 1883-'84, a distance of about 46 miles; of the completion of the survey of Reelfoot Lake and the bluffs behind it, begun the year before, and of a survey from Grand Tower down to Hacker Towhead, 25 miles above Cairo, a distance of about 52 miles, and extending down the right bank to Buffalo Island, half a mile farther. A field report of this work, made by Mr. Winchell June 12, 1885, is appended hereto, and attention is invited to it and to its attached list of bench-marks established from Grand Tower to Buffalo Island.

PREPARATION AND PUBLICATION OF MAPS.

From the date of the last report of the secretary to the end of the fiscal year the following, adapted from a memorandum furnished by Mr. Ockerson, assistant engineer, shows the progress made in this department. Eleven detail charts, scale 1 : 10,000, extending from the head of Bordeaux Chute to Saint Louis Landing, a distance of 71 miles, have been finished except the titles and notes. The topographical signs have been printed on nineteen charts in addition to the above. Eighteen detail charts have been projected, and sixteen of them have been transferred and the outlines have been inked. Twelve of these charts lie between Grand Tower and Cairo, and six lie between New Madrid and Caruthersville. The latter were also lettered. Twenty-three detail charts, scale 1: 10,000, covering the following Old River lakes and tributaries, have been projected and finished, with the exception of titles and notes: Bayou de Chien and bluffs, below Hickman, Ky.; Flower Lake, Beaver Dam Lake, Moon Lake, Horseshoe Lake, and head of Sunflower River, Lake Lee, Bunch's Lake, Lake Providence, Eagle Lake, Yazoo Lake, Lake Saint Joseph, Lake Bruin, Lake Saint John, and Lake Concordia, each in one chart; Saint Francis River from opposite Walnut Bend to mouth, Palmyra Lake, and Red River from opposite Black Hawk Landing to mouth, each in two charts, and Reelfoot Lake in three charts. Four sheets of the series on a scale of 1 to 20,000 have been published; two of them are in the vicinity of Saint Louis Landing, and two covering the Lake Providence Reach. Nine sheets of this series have been published so far, and the material has been prepared for thirty others. These two items embrace that portion of the river extending from Island No. 63 to Donaldsonville, a distance of 550 miles. The index charts, titles, and scales for the same series for twenty-eight sheets above Island No. 63 have also been completed.

The positions of stone line bench-marks have been computed and tabulated from New Madrid to Caruthersville and Saint Louis Landing to Leota. This embraces some fifty-six stone lines and two hundred and twenty bench-marks.

Work on the preliminary chart—scale, 1 inch to 1 mile—has been continued. One sheet near the Head of the Passes has been completed, and a part of one sheet near Donaldsonville. One title-page and one sheet of notes, table of distances, &c, have been engraved. Three index-sheets have been prepared for photolithographing. Six sheets from Jackson's Point to Donaldsonville, one sheet at the Head of the Passes, and two sheets of titles and notes have been printed.

A map of the Alluvial Valley was commenced, which will show the area overflowed, and will exhibit sections across the alluvial region referred to the level of the gulf as

a datum plane, and the water-surface of the overflow of 1882 will be indicated upon the sections. The map will in addition show the lines of levees in existence, besides other features of note, and will give much information of interest and value. The map comprises eight sheets, each 22 by 29 inches, on a scale of 1 inch to 5 miles, and extends from Cape Girardeau on the north to the Gulf of Mexico, and is of sufficient width to embrace the several basins of the lower river. The river and adjacent detail is derived from the recent surveys made by the Mississippi River Commission, General Comstock and the United States Coast Survey; the transalluvial profiles are from surveys of the Mississippi River Commission, Humphreys and Abbot, and railroads. The remainder of the map is derived from maps of various kinds, embracing the best data extant. It will soon be ready for printing. The following summary, indicating the condition and progress of the work upon the charts, is of interest.

The outline series embraces shore-lines and soundings, with a strip of say 200 or 300 meters of topography, from Island No. 1 to the head of Frame's Chute, joining General Comstock's previous survey, 36 charts; from Commerce Cut-off to O. K. Landing, joining General Comstock's previous survey, 4 charts; and from Delta, Miss., to Saint Louis Landing, joining at its upper end General Comstock's previous survey, 5 charts; making a total of 45 outline charts, of which 14 are completed with titles, notes, &c., and 31 require only the titles and notes.

The topographical series cover the region from Island No. 1 to the head of Frame's Chute, 34 charts; from Commerce Cut-off to Donaldsonville, 101 charts; and from Grand Tower to Hacker Towhead, 12 charts; making a total of 147 charts, of which 100 are finished except titles, &c., the conventional signs are required on 28 charts, the lettering on 10 charts, the outlines are yet to be inked on 2 charts, and the titles, notes, &c., are required on all of them.

The Old River Lakes comprise 23 charts, all of which are finished except titles, &c. The series, on a scale of 1 to 20,000, will comprise 67 charts besides index, titles, &c., of which 9 are published and the material is prepared for 30 others, all below Island 63, and the index charts, titles, and scales for 28 sheets above Island 63 are completed.

The preliminary map, scale 1 inch to 1 mile, comprising 32 sheets, 3 index sheets, and 2 sheets of titles and notes, is all printed except the 3 index sheets, now ready for photolithographing, and the series will be complete for distribution in a few weeks.

The compilation of stone line bench-marks is completed from Cairo to Leota, 512 miles, leaving the 372 miles from Leota to Donaldsonville yet to do.

The series, on a scale of 1 to 10,000, will comprise 215 manuscript charts, of which 168 are finished except titles, &c.

In this department the printing of conventional signs upon the manuscript maps, alluded to and described in the last annual report, has been continued and perfected, and it is the intention to submit a supplementary report with description and illustrations compiled by Mr. Ockerson, the chief of the topographical division.

DISCHARGE OBSERVATIONS.

Preparations for this work were begun in August, the principal parts of the meter plant were designed, and this plant and three iron launches, similar to those previously used, but having double engines, were ordered. The parties were in the field at about the end of September, being stationed as follows:

Near New Madrid (Point Pleasant, Mo.), in charge of Assistant E. E. Haskell.
At Helena, in charge of Assistant A. H. Weber.
At Arkansas City, in charge of Assistant G. W. Wood.
At Warrenton, in charge of Assistant J. W. Dorst.
At Red River Landing, in charge of Assistant H. P. Ritter.
At Carrollton, in charge of Assistant M. K. Bowen.

The observations at Red River Landing embrace measurements of discharge of the Mississippi River below the mouth of Red River, of the Atchafalaya near its head, and of Old River between the Atchafalaya and the Mississippi.

Work at all the stations was continued throughout the winter, with many interruptions from running ice in the upper river and from heavy winds and fogs below. No appropriations having been made in the late session of Congress, the cessation of this work became necessary, and at the end of March the withdrawal and disbanding of the parties were ordered, the services of Assistants H. P. Ritter, E. E. Haskell, and G. W. Wood being retained. The reduction of the notes of these observations is now in hand, and when completed the results, with reports, will be presented for publication.

An attempt was made to make comparative observations for discharge with meters and double floats, but the compulsory withdrawal of the parties interrupted them before they were fairly inaugurated.

GAUGE INSPECTION.

Experience has demonstrated that the records of a series of gauges become very unreliable, and in many instances entirely useless, unless the gauges be subjected to

frequent inspections to check the recorded readings of the observers, to replace disturbed or lost sections of the gauges, and to check the elevations of the divisions by connecting them instrumentally with established bench-marks. These inspections have been made, as heretofore, by Assistant John Ewens, who determines the error, if any, existing in the elevations on the gauges, repairs the gauges and the bulletins, and reports the result of each inspection of each gauge to this office, by which the reported readings are checked. The steamer Patrol, built for that purpose principally, had been used for visiting the gauges up to the end of April, when lack of funds compelled us to lay the boat up and disband the crew. Since that time arrangements have been made to visit the gauges, making use of the passenger steamers and other modes of travel. Mr. Ewens takes with him one man, to assist, with a level, and such smaller tools as are found necessary, a maul, driving-cap, and a small supply of lumber being sent to each station for use as required. Seven gauges, deemed of least importance or most troublesome, have been discontinued from lack of funds. Weekly reports are rendered by each observer, the readings are plotted and examined in the computing division, and any found in error are reported and the observer called upon to repeat the record.

The year of observation of the tide-gauge at Biloxi, Miss., ceased on June 10, and the property pertaining to the station was shipped to this office.

OPERATIONS OF THE STEAMER PATROL.

The report of the Secretary in the annual report of the Commission for 1884 explains the necessity for this boat. During the last fiscal year it has been used for transporting Assistant Ewens, in charge of gauge inspections, from point to point, which are its regular duties. By its use examinations were permitted of Waterproof Cut-off and surveys in front of the Davis and Bonnet Carré crevasses, soundings at shoals or crossings were made in July and August, and snags discovered in the channel were reported. Two launches were towed from Cairo to Saint Louis for repairs in August. During the entire month of September and up to the middle of October the boat was engaged in distributing launches and quarter-boats for the observation parties, transporting subsistence and supplies for the topographical party, and in towing the new launches from Dubuque to their stations, passing over the river from Saint Louis to Vicksburg and return, thence to Dubuque, and down the river to New Orleans. By its use low-water benches were connected below Vicksburg to Red River Landing, and the Commission were transported in an examination of the Atchafalaya. On December 30 the boat was forced from Cairo up the Mississippi River for 25 miles, and returned with the topographical-survey boats, which were in an unsafe location. With the Patrol the Secretary made an inspection of the field and office work at the six discharge stations in January, rating the meters according to an improved method. The steamer was used in March to transport Assistant L. L. Wheeler, accompanied by Assistant F. B. Maltby, down the river for the purpose of making experimental observations with meters and double floats, and when the observation parties were recalled it was used to tow the launches and quarter-boats of the five lower stations to Twin Hollows. While performing these special or incidental duties the gauges were inspected as necessity seemed to require, and repairs made. One hundred and eleven gauge visitations were made July to April, inclusive, none being made in September. The number of visits made per month varied from five to twenty-four, and the visits to individual gauges in the entire time varied from one to ten.

Attention is invited to the fact that when the survey boat Pioneer was sunk, as noted in Mr. Winchell's report, several of the assistants lost considerable personal property, consisting of clothing, professional books, &c. This loss was incident to the service upon which they were engaged, was entirely without fault of theirs, and due to causes beyond their control, and remuneration would seem to be but just and proper.

The failure of additional appropriations has rendered a reduction of force necessary, which was much to be regretted, and has caused a cessation of important work, and will make it impossible to provide for valuable observations and operations during the coming season and in the next period of high water and probable overflow. Other matters will be reported on from time to time and reports forwarded as the material is prepared and completed.

Very respectfully, your obedient servant,

THOMAS TURTLE,
Captain of Engineers,
Secretary Mississippi River Commission.

General Q. A. GILLMORE,
President Mississippi River Commission.

Itemized statement of expenditures for Mississippi River Commission, appropriation of July 7, 1884.

Items.	Services assistant engineers, &c.	Services rodman, &c.	Outfit.	Supplies.	Subsistence.	Fuel.	Repairs.	Transportation.	Mileage and traveling expenses.	Miscellaneous.	Totals.
Salaries of commissioners											$9,000 00
Mileage and inspection		$1,290 60		$18 74	$1,217 41	$961 31		$52 75	$3,063 23		6,604 04
Salaries and traveling expenses of assistant engineers	$28,511 13							297 65	86 65		28,895 43
Publication of maps	1,522 45			1 40				2 10		$415 50	1,941 45
Gauges	185 00	1,319 34	$15 45	24 82	85 13	126 50	$21 04	19 70			1,797 58
High and low water marks		245 80	25 65	98 60	181 35	299 50	137 77	13 15	5 71	13 50	1,021 03
Reduction of field work	1,563 87	1,591 96	99 66	71 05				20 30			3,346 84
Hydrography and topography	72 35	484 50		33 00							589 85
Totals	$31,854 80	4,932 20	140 76	247 61	1,483 89	1,387 31	159 41	405 65	3,155 59	429 00	53,196 22
Office:											
Services clerks, &c										8,726 58	
Rent										1,200 00	
Fuel										393 19	
Professional works, &c										22 20	
Furniture										43 67	
Supplies										218 96	
Transportation										174 12	
Stationery										518 83	
Telegrams										106 94	
Miscellaneous										237 41	
											11,677 90
											$64,874 12

SUMMARY.

Balance from appropriation March 3, 1883	$12,528 61
Appropriation by act July 7, 1884	75,000 00
Cash deposited, sale of fuel to officers	66 75
Total	87,595 36
Expenditures for fiscal year ending June 30, 1885	64,874 12
Balance	22,721 24

THOMAS TURTLE,
Captain of Engineers,
Secretary and Disbursing Officer Mississippi River Commission.

Itemized statement of expenditures for surveys of Mississippi River, act of July 5, 1884.

Items.	Services assistant engineer, &c.	Services draughtsmen, rodmen, &c.	Outfit.	Supplies.	Subsistence.	Fuel.	Repairs.	Transportation.	Traveling expenses.	Miscellaneous.	Medical supplies.	Totals.
Observations	$9,999 76	$52 00	$9,654 01	$899 69	....	$940 81	$1,370 62	$1,345 51	$13 80	$67 50	$16 30	$24,360 00
Publication of maps	....	....	....	....	....	....	....	....	....	....	....	854 50
Reduction and publication	2,565 00	830 00	223 79	458 64	....	....	....	34 92	....	50	....	4,112 85
Field work of topography	5,596 71	....	91 58	846 72	$1,548 01	147 46	780 90	604 42	....	7 50	....	9,623 30
Inspection and maintenance of gauges	7,306 75	1,319 34	724 87	561 76	963 74	1,828 86	930 51	23 80	....	192 25	74 45	13,926 33
Miscellaneous surveys	....	2,317 74	74 86	195 49	262 57	998 65	45 85	105 70	8 85	53 70	....	4,063 41
Care of property	....	1,676 00	79 65	118 89	....	....	....	36 50	....	....	....	1,911 04
Totals	25,468 22	6,195 08	10,848 76	3,081 19	2,774 32	3,915 78	3,127 88	2,150 85	22 65	321 45	90 75	58,851 43

SUMMARY.

Appropriation by act July 5, 1884	$75,000 00
Expenditures for fiscal year ending June 30, 1885	58,851 43
Balance	16,148 57

THOMAS TURTLE,
Captain of Engineers,
Secretary and Disbursing Officer Mississippi River Commission.

Approximate value of plant belonging to the United States and used by the Mississippi River Commission in making surveys and examinations of the Mississippi River, appropriation "Mississippi River Commission."

Class of property.	Approximate value June 30, 1885.
One steamer, Patrol	$14,600 15
Three launches, Nos. 1, 2, 3	6,000 00
One steam-tug, Frolic	2,000 00
Seven quarter-boats	15,310 35
Skiffs, &c	800 00
Outfit	5,222 08
Tools and appliances	1,068 22
Surveying instruments	12,641 76
Drawing instruments	778 00
Office furniture	851 35
Printing press, &c	326 05
Current meters and outfit	1,976 50
Total	61,574 46

Appropriation, "Surveys of Mississippi River".

Class of property.	Approximate value June 30, 1885.
Three launches, Nos. 4, 5, and 6	$8,286 00
Current meters and outfit	884 00
Outfit	271 71
Tools and appliances	138 70
Total	9,580 41

Respectfully submitted.

THOMAS TURTLE,
Captain of Engineers,
Secretary Mississippi River Commission.

SAINT LOUIS, *July* 23, 1885.

O 1.

REPORT OF C. M. WINCHELL, ASSISTANT ENGINEER, ON FIELD WORK OF TOPOGRAPHY AND HYDROGRAPHY.

OFFICE MISSISSIPPI RIVER COMMISSION,
2828 WASHINGTON AVENUE,
Saint Louis, June 12, 1885.

SIR: I have the honor to submit the following report on the field-work of the topographical party under my direction during the season of 1884-'85:

In obedience to instructions from Capt. Smith S. Leach, Secretary Mississippi River Commission, I left Saint Louis September 27, 1884, with the following assistants: C. W. Clark, O. W. Ferguson, H. B. Wood, L. C. Jones, H. W. Kerr, F. B. Maltby, O. A. Orrman, M. Greenwood, jr., G. H. French, and recorders D. E. Perkins and Isaac Purcell. The crew had been ordered to report at Cairo September 28.

The instructions directed me to go to Cairo, Ill., take the quarter-boats Tennessee and Pioneer and tug Frolic, and proceed to a point near the Kentucky-Tennessee State line to resume the survey where the work of the preceding season ended, and continue the same down the river to Caruthersville, Mo., closing on the upper limit of Assistant L. L. Wheeler's work of 1883-'84.

After finishing this reach I was directed to have the boats and party towed to Grand Tower, Ill., and make a survey of the river from there to Cairo, Ill., closing on the

upper limit of the work of the United States Lake Survey of 1876–'77. We reached Cairo September 28, and went at once on board the quarter-boats. The Frolic was on the docks undergoing repairs. I therefore engaged the tug Ariadne to tow the boats, including Mr. Haskell's quarter-boat Kentucky and iron launch, to New Madrid, Mo., which point was reached September 30, and work began the same day. Topographer French and three men were landed at Hickman, Ky., September 29, with instructions to proceed to Reelfoot Lake and complete the survey of that lake and the bluffs behind it, which was begun the year before. The Frolic arrived from Cairo October 14, the party having been deprived of the services of a tug for fifteen days. One of the advantages of having a steam-tug with a party of this kind is shown by the different rate of progress made. In fifteen days without the Frolic the party surveyed 17 miles of river. During the next sixteen days with the Frolic we surveyed 29 miles. This gain is chiefly due to the saving of time in getting the field parties to and from work, about an hour being gained at each end of the day.

Mr. French rejoined the party October 15, having finished the survey of Reelfoot Lake and connected it with the main river survey. It was found necessary to carry a system of tertiary triangulation over this entire reach, to check the stadia work, the secondary triangulation stations, which were built in 1879–'80, being all caved in the river or destroyed except two at Island 14 and two at Island 15.

The survey was completed to Caruthersville November 1, previous to which date I had been directed by Captain Leach to wait at Caruthersville for the steamer Oakland to tow the quarter-boats to Grand Tower. The Oakland arrived and took the boats in tow on the evening of November 6, the time between the 1st and 6th being occupied by the party in office work, repairing and painting skiffs and stadias, scrubbing quarter-boats, and getting up a supply of stove-wood. About 10 p. m., October 6, when about one mile below Point Pleasant, Mo., the Pioneer ran under and sank, one end and part of one side of the cabin being carried away. The sinking was caused by pulling out of an eddy to pass a projecting clay point and suddenly encountering a very rapid current. There were a dozen men on the Pioneer at the time of the accident, part of them in bed, all of whom escaped by climbing out through the sky-lights, and were picked up in skiffs. We then succeeded in landing the wreck of the Pioneer near Lazelles Landing, Missouri, when I, with Topographer Ferguson and three men went ashore to recover what property we could from the wreck, all of the surveying instruments, transits, theodolites, levels, and level-rods being on the Pioneer, besides a good deal of personal property. The Oakland went on up the river with the other boats and the party, in charge of Assistant C. W. Clark. November 7 we recovered all the instruments except one Stackpole transit, and sent them at once to Grand Tower in charge of Mr. Ferguson. November 8, the United States steamer Mississippi arrived and raised the Pioneer when the missing transit was found under a stove. The Pioneer and what property was saved on her was left with Assistant E. E. Haskell, who was stationed at Point Pleasant, and whose receipt I took for the same. I left Point Pleasant November 10, and rejoined the party at Grand Tower November 12, stopping one day in Cairo to arrange for the towing to Grand Tower of the quarter-boat Mississippi to take the place of the Pioneer. The party reached Grand Tower November 8, and began work Monday, November 10, a part of the men being quartered at farmhouses until the Mississippi arrived November 17.

December 9, Topographer Maltby was taken sick with malarial fever, and on December 19, was sent home on sick leave. Recorder Perkins also went home, sick, on December 24.

December 17 the survey was completed to Hacker Towhead, below Commercial Point, Illinois, on which date ice began to run in the river rendering it impossible to cross the river in a skiff afterward for several weeks.

The work on the right bank was carried down to Buffalo Island, closing on stone-line No. 6, but there was no field work done after December 18.

From December 18 to December 30, the assistants were engaged in reducing field notes, plotting, &c., and the crew in felling and hauling trees from the neighboring woods to build log booms to prevent the boats from being cut down by the ice.

December 30, the United States steamer Patrol arrived with Captain Leach on board and the boats were taken to Cairo and laid up. The party was paid off and disbanded December 31, when I returned to Saint Louis with the assistants who were retained.

TOPOGRAPHY.

The usual topographic features were located, bayous, sloughs, swamps, fields, roads, and houses, the elevation of the ground being determined by vertical angles at nearly every point which was located to aid in sketching contours.

From September 30 to November 1, there were twenty-nine working days. The total area surveyed was 153¼ square miles or 5.3 square miles per working day. The

length of main river surveyed is 46 miles, which gives a daily rate of progress of 1.6 miles.

On the upper reach, Grand Tower to Buffalo Island, the river follows the bluffs on the right bank to Cape Girardeau, where there is an opening in the bluffs extending to Gray's Point. This opening has a river front of 4 miles and is the first outlet for the Mississippi River floods to the Saint Francis Basin. From Gray's Point the bluffs border the river on both sides for a distance of 7 miles to Commerce, Mo., where they leave the river. On the left bank the bluffs from Grand Tower to Sexton Creek are from 3 to 5 miles east of the river. This line of hills was also located as well as numerous creeks and lakes between the bluffs and the river. On this reach of river the total area surveyed was 159 square miles. From November 10 to December 17 we had thirty-two working days, on two of which it rained all day. This gives an area of 5.3 square miles surveyed each working day. The length of main river is 52 miles, or 1.7 miles per day. The secondary triangulation stations upon which this survey was based were so far apart, and, on the east side so far back from the river that a tertiary system was carried over the entire reach, except that part between Gray's Point and Commerce, Mo.

HYDROGRAPHY.

Three hundred and eighty-nine cross-sections were sounded and a longitudinal line along the channel. The soundings were located by double sextant angles, the observers being in the sounding cutter and reading angles between signals on shore which had been located by the topographers. Care was taken to get many more soundings on shoal crossings than elsewhere. The deepest water found was opposite Grand Tower, 112 feet, and the shoalest section at Crawford's, above Neely's Landing, where 9 feet was the best water at the time of making the survey. Beaver Dam Rock, opposite Burnham's Island, is nearly in the channel of the river at that point. At low water it projects 3 feet above the surface, and is a dangerous obstacle to navigation a large part of the year. It could easily be blasted out, being probably a large detached bowlder.

LEVELS.

On the lower reach a continuous line of levels was run on one bank and river crossings made at each stone line to determine the elevations of the stones furthest back from the river, which had not previously been done. Where these stones had been destroyed new ones were set, and the position and elevation of the top of the stone determined. The elevation of the top of the bank and of the water-surface was determined at each sounding section. All water-gauges and well established high-water marks were connected with.

On the upper reach two lines of levels were run most of the way, one on each bank, checking each other by water-surfaces and by river crossings at each stone line. Seventeen stone lines were established on this reach, the positions and elevations of the tops of the stones being well determined. Bench-marks were also made of triangulation stations, and stones set by other parties. All bench-marks depend for their values on precise bench-marks previously established by the Mississippi River Commission, and are referred to the Memphis Datum Plane.

RÉSUMÉ.

Miles of river surveyed	98
Square miles topography	248
Square miles hydrography	54
Square miles total area	302
Number of soundings	21,088
Number of sextant angles	9,961
Number of working days	59

There are yet 25 miles of river to survey to finish the work assigned to the party last year.

Very respectfully, your obedient servant,

C. M. WINCHELL,
Assistant Engineer.

Capt. THOMAS TURTLE,
Secretary Mississippi River Commission.

Table of bench-marks established, Grand Tower to Buffalo Island.

Designation.	Locality	Elevation.	Remarks.
		Feet.	
B. M. $\frac{22}{1}$	1½ miles above Grand Tower	368. 26	In Illinois.
B. M. $\frac{22}{2}$	......do	373. 64	Do.
B. M. $\frac{22}{3}$	......do	430. 39	In Missouri.
B. M. $\frac{21}{1}$	2 miles below Grand Tower	363. 25	In Illinois.
B. M. $\frac{21}{2}$	......do	364. 17	Do.
B. M. $\frac{21}{3}$	......do	360. 65	On Grand Tower Island
B. M. $\frac{20}{1}$	1 mile below mouth of Big Muddy River	357. 63	In Illinois.
B. M. $\frac{20}{2}$	......do	359. 62	Do.
B. M. $\frac{20}{3}$	½ mile below mouth of Apple Creek	372. 74	In Missouri.
B. M. $\frac{19}{1}$	¾ mile below Spring Landing, Illinois	357 20	In Illinois.
B. M. $\frac{19}{2}$	......do	355. 25=stone 360. 34=pipe	Do.
B. M. $\frac{19}{3}$	½ mile below Dog Creek	352. 83	In Missouri
B. M. $\frac{18}{1}$	1½ mile below Neely's Landing	361. 23	In Illinois.
B. M. $\frac{18}{2}$	...... do	352. 85=stone 357. 99=pipe	Do.
B. M. $\frac{18}{3}$	½ mile below Indian Creek	362. 99	In Missouri.
B. M. $\frac{17}{1}$	Opposite Moccasin Springs Landing	350. 38=stone 355. 48=pipe	In Illinois.
B. M. $\frac{17}{2}$	......do	353. 60	Do.
B. M. $\frac{17}{3}$	¼ mile below Moccasin Springs Landing	370. 31	In Missouri
B. M. $\frac{16}{1}$	¼ mile below Bainbridge Landing	344. 92=stone 350. 00=pipe	In Illinois.
B. M. $\frac{16}{2}$	......do	349. 34	Do.
B. M. $\frac{16}{3}$	......do	360. 88	In Missouri
B. M. $\frac{15}{1}$	1 mile above head of Devil's Island.	348. 45=stone 353. 64=pipe	In Illinois.
B. M. $\frac{15}{2}$	......do	352. 04	Do.
B. M. $\frac{15}{3}$	1 mile below Poe's Landing	350. 36	In Missouri.
B. M. $\frac{15}{4}$	......do	354. 09=stone 359. 19=pipe	On left bank of Flora Creek.
B. M. $\frac{14}{1}$	¼ mile below foot of Devil's Island.	341. 70=stone 346. 80=pipe	In Illinois.
B. M. $\frac{14}{2}$	......do	350. 22	Do.
B. M. $\frac{14}{3}$	1 mile above Cape Rock	390. 36=stone 395. 44=pipe	In Missouri.
B. M. $\frac{13}{1}$	½ mile below Waboo, Ill	343. 86=stone 348. 96=pipe	In Illinois
B. M. $\frac{13}{2}$	......do	345. 26	Do.
B. M. $\frac{12}{1}$	3 miles below Cape Girardeau	345. 04=stone 350. 13=pipe	Do.
B. M. $\frac{12}{2}$	......do	344. 65	Do.
B. M. $\frac{12}{3}$	......do	344. 68	On left bank of Cape La Croix Creek.
B. M. $\frac{12}{4}$	...... do	342. 03=stone 347. 13=pipe	In Missouri.
B. M. $\frac{11}{1}$	Opposite Gray's Point	336. 42=stone 341. 51=pipe	In Illinois.

Table of bench-marks established, Grand Tower to Buffalo Island—Continued.

Designation.	Locality.	Elevation.	Remarks.
		Feet.	
B. M. $\frac{11}{2}$	......do	340.23	In Illinois.
B. M. $\frac{10}{2}$	½ mile below Thebes	358.27	Do.
B. M. $\frac{10}{3}$	......do	353.00	In Missouri.
B. M. $\frac{9}{2}$	1 mile above Santa Fé	367.30	In Illinois.
B. M. $\frac{9}{3}$	¾ mile above Commerce	350.19=stone 355.27=pipe	In Missouri.
B. M. $\frac{8}{1}$	1½ miles above Atherton Landing	333.17=stone 338.27=pipe	In Illinois.
B. M. $\frac{8}{2}$	......do	340.47	On Burnham Island.
B. M. $\frac{8}{3}$	2½ miles below Commerce	339.19	In Missouri.
B. M. $\frac{8}{4}$	......do	333.67=stone 338.76=pipe	Do.
B. M. $\frac{7}{1}$	1 mile above Commercial Point	338.75=stone 343.85=pipe	In Illinois.
B. M. $\frac{7}{2}$	......do	337.29	Do.
B. M. $\frac{7}{3}$	On Powers Island	Not leveled to	In Missouri.
B. M. $\frac{7}{4}$	......do	do	Do.
B. M. $\frac{6}{3}$	½ mile below Price Landing	Not det'rm'd	Do.
B. M. $\frac{6}{4}$	......do	do	Do.
△ Simpson 249	1½ miles above Grand Tower	350.23	Do.
* Flag 42	1 mile below Big Muddy River	355.14	In Illinois.
* Flag 43	½ mile below Hines Landing	366.64	Just below mouth of Apple Creek.
* Flag 44	150 meters above B. M. $\frac{19}{2}$	355.06	In Illinois.
△ Indian Creek	Back of B. M. $\frac{19}{3}$ on bluff	481.92	In Missouri.
* Flag 45	½ mile below Devil's Tea Table	503.66	Do.
* Flag 49	½ mile below Bainbridge Landing	352.46	Do.
* Flag 50	1 mile below head of Devil's Island	352.05	In Illinois.
* Flag 51	1½ miles below head of Devil's Island.	349.74	In Missouri.
* Flag 52	1 mile above foot of Devil's Island	346.91	½ mile above Big Flora Creek.
* Flag 53	On Cape Rock	432.68	In Missouri.
* Flag 54	Opposite Cape Rock	350.80	In Illinois.
△ Cape Girardeau	In upper edge of Cape Girardeau	439.48	In Missouri.
* Flag 55	Opposite Cape Girardeau	346.94	In Illinois.
* Flag 56	3 miles below Cape Girardeau	342.47	On river bank in Missouri
* Flag 57	½ mile south of B. M. $\frac{12}{1}$	344.35	In Illinois.
△ Cape La Croix	On Gray's Point	480.67	In Missouri.
△ Grand Chain	Opposite Thebes on bluff	439.03	Do.
△ Day	1 mile above Thebes	473.67	In Illinois.
△ Hofner	¾ mile above Commerce	516.40	In Missouri.
△ Burnham	On Burnham Island	338.79	In Illinois.
△ Atherton	1 mile back of Atherton Landing	336.75	Do.

*Stone set by triangulation parties.

C 2.

REPORT OF ASSISTANT ENGINEER J. A. OCKERSON, ON MECHANICAL DEVICE FOR PRINTING TOPOGRAPHICAL SIGNS AND LETTERS ON ORIGINAL MAPS. AND DESCRIPTION OF A NEW FORM OF PROTRACTOR FOR PLOTTING POLAR CO-ORDINATES.

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., June 18, 1885.

SIR: I have the honor to submit the following report on a mechanical method of printing conventional signs on original maps:

In my report of last year, an extract from which is published in the Commission Report, 1884, page 41, an account is given of the experiments which resulted in a satisfactory solution of that part of the problem which relates to the production of suitable stamps or types. Since then the details of manipulation have been solved, and printing the conventional signs has taken the place of the former tedious method of hand-work. Thirty charts have been printed so far, and the results justify the statement that the device is satisfactory both as to the quality and quantity of work done.

The device as now used consists of a wooden cylinder 3 inches long and 4 inches in diameter, covered with rubber one-eighth inch thick, and around this is fixed a very thin electrotype shell of the proper sign, and the whole provided with an adjustable handle, which gives it the appearance of a short rolling-pin. (See Figure I, *w–w.*, wooden roller, *r–r*, rubber backing for electrotype shell; *s–s*, electrotype shell, about as thick as ordinary letter paper; *h–h* is the adjustable handle, which can be used with different rollers.)

Figure II is the ink roller with its supporting frame.

The rubber backing and the copper shell, which is very thin, gives sufficient elasticity to admit of printing through a stencil, and the cylinder on which they are placed makes it easy to apply sufficient pressure by hand, as there is only one line in contact with the paper at a time. The size of the cylinder adopted was found, after experiments with various sizes, to give the best results for easy manipulation by hand.

Before printing the signs, the maps are all drawn in outline, and the lettering is printed on them, and it becomes necessary to cover such detail as will be interfered with by the signs. On the solution of this part of the problem the success of the printing process very largely depended, as it must necessarily be quickly and easily done. After much experimenting, with indifferent results, a starch pencil was finally hit upon, which satisfied every requirement. A hard piece of common starch rubbed once over the lettering or other detail will prevent the ink on the sign-roller from adhering, and after the signs are printed the starch can be easily brushed off, leaving the matter clear and sharp.

In using the sign-printing device, the first step is to prepare stencils of the size and shape of the different fields or kinds of vegetation or other matter which it is desired to represent. A thin tracing paper is the best for this purpose, and stencils for an entire sheet should be prepared before beginning the work of printing. The ink should be the best quality of printers' ink that will dry quickly, and it should be evenly distributed on the ink-roller by first rolling it down flat and smooth on a piece of glass by means of a hand-roller, then passing the ink-roller over the glass plate a few times.

To ink the type cylinder the latter is revolved in contact with the ink-roller till it carries sufficient ink.

In order to get a uniform impression it is essential that the table on which the printing is done should be perfectly smooth and true, as a ridge would show itself in a dark streak and a hollow would give a light or possibly no impression.

When everything is ready for printing, the stencil is laid on the map in its proper place, and the type cylinder, properly inked, is rolled slowly over it, sufficient pressure being applied to the handle to give the required impression. The latter will vary with the quality of paper.

It is evident that the stencil will fix the shape of the field, and if the latter is smaller than the surface of the type cylinder, about 3 by 12 inches, it will all be printed at one movement. If the area is too large for the cylinder, the latter must be inked and the rolling process repeated till the required area is covered. The signs which are in straight lines and regular figures, such as cotton, &c., can easily be matched by inspection, as the roller will always run perfectly true if started properly; for the other signs, like woods, sand, &c., it is best to lay a strip of paper so as to come just to the edge of the printed portion, and, covering it, then let the cylinder overlap a little. For sand it is necessary to leave a narrow strip near the water's edge to be put in by hand, as the stamp can only give a flat tint.

A sample of the work done is submitted herewith.

For an antiquarian sheet with the usual amount of work, say 18 by 40 inches, it re-

quires about two days for one man to prepare the stencils and do the printing. The same work would employ a good draughtsman nearly a month.

The stamp for printing letters and figures, which is mentioned in the Commission Report of 1884, page 40, is a valuable adjunct to the sign-printing device, and a detailed drawing of it is also submitted.

Figure 1 is a front view of the instrument with the type holder (*t*) in place. A section of the latter is shown at (*s*). Figure 2 shows the base. Figure 3, the piston with the type-holder removed, and showing a section (*a*); the spiral spring which lifts it to its proper place after the name has been printed (*b*); the guide slot (*c*) through which the pin (*e*), Figure 1, passes; (*d*) the pin which holds the type holder or figure-disks in place. Figure 4 is the type-holder detached from piston. Figure 5 is a figure-disk, the slots in which are of a size suited to the type used. Figure 6 is the frame which is cast in one piece, and sections are shown in connection with it.

By the use of the two devices described above the work of mapping is very much facilitated. In a large series of maps it also has the advantage of giving uniform results, which cannot be done when the work is performed by many different hands. The maps can be made for about one-third of the cost when made by hand.

Any desired style can be made use of, as the photo-electrotype process admits of producing stamps from the work of the best draughtsmen.

By this process the work of making hydrographic maps, where the depths are shown by different shades of sanding, becomes very simple and quite rapid.

The rapidity with which work can be done would admit of its being used on original-survey plats, thus adding very much to their value by giving more information as to the character of the lands, boundaries of swamps, timber areas, &c.

If desired, the instrument could be made larger by using mechanical appliances to give the necessary pressure; but unless the amount of work to be done is very great, the simple device mentioned will be found preferable.

This process is well suited to work which is to be reduced by the photographic method, or the map may be published directly by the following means: Draw the outlines and print the letters and figures in lithographic ink on suitable paper, and transfer the same to zinc or stone. From this take a light impression, called an offset, which will show in faint lines the outlines of the transferred map. Print on this with lithographic ink the conventional signs, and transfer to the plate which bears the outlines.

From the plate or stone thus prepared any number of copies can be struck off. It would be better to use zinc than stone, as the plates could be filed away and kept as the originals, and if another edition should be required it could be made use of. This method, used in conjunction with the printing device described above, admits of multiplying copies of a map at a minimum cost.

In the case of land-survey plats above noted, if the originals were prepared on zinc as described, copies could be furnished at a small fraction of the cost by the present method, and each copy would have the advantage of being free from errors which are apt to occur in hand-made copies.

As platting of surveys is closely related to the question of mapping, it may be of interest to give a brief description of a protractor that I have designed for doing this work. It is essentially a semicircular protractor, provided with a needle-pointed pivot at its center and having the straight edge graduated so that distances can be measured off each way from the pivot, while the angular deflection is given by the graduated circle, reading from a point marked on the paper.

The details are shown in a drawing submitted herewith. A section of the pivot plate is shown in Fig. II. The bottom of the plate is flush with the bottom of the protractor, and the hole F is at the center, and should be only large enough to admit a fine needle. The screw D has a hole drilled in its axis to admit the needle-point. It is also split, so that when it is screwed down it will clamp the needle firmly. If the latter is broken, it can readily be replaced by a new one.

In addition to the scale on the beveled edge, a diagonal scale is also provided as shown, and we have in one instrument all the requisites for rapid and accurate platting of points located by polar co-ordinates or by intersections.

In using this protractor the needle-point is placed at, say, the first station, and pressed firmly down.

A meridian line is then decided upon, and a point is marked on it at the outer edge of the protractor circle, and this will be the initial point from which the angles will be read. As azimuth is reached from the south around by the west, it is plain that the circle, numbered as shown and revolved about the pivot till the proper reading coincides with the meridian line, will give the direction of the required point along the graduated diameter, while from the latter the distance can be pricked off. A point can be platted in any direction without lifting the protractor from its position.

In going to the second station it is not necessary to draw a meridian line through it. The azimuth between the first and second stakes being known, if the pivot be set at the latter, and the protractor revolved so that the straight edge coincides with the

line passing through the two stakes, then the point on the circle corresponding to the azimuth of the line will be a point on the meridian line. This point being marked on the paper is the origin for the angles platted from the second station, and it is evident that they will bear the proper relations to the points platted from the first station.

The same kind of pivot attached to a triangular scale will facilitate platting where many measurements are required from the same point in different directions; or it can be used in connection with a paper protractor with the interior portion cut out, the pivot of the scale being at the center.

Both of these instruments have been tried and the results have been very satisfactory. The platting can be done more rapidly than by any method we have heretofore used, and the work is equally accurate. It also does away with the use of cumbersome tools, such as rulers, triangles, &c., which, in field platting especially, are hard to manipulate.

Very respectfully, your obedient servant,

J. A. OCKERSON,
U. S. Assistant Engineer.

Capt. THOMAS TURTLE,
Secretary Mississippi River Commission.

ACCOMPANYING PLATES.

(1) Details of sign-roller and letter-stamp.
(2) Specimens of work done with above.
(3) Drawings of protractor.
(4) Sample of lithograph from printed signs.

C 3.

REPORT OF ASSISTANT ENGINEER L. L. WHEELER UPON REDUCTION OF OBSERVATIONS FOR DETERMINING ELEVATIONS AND SLOPES OF HIGH AND LOW WATER SURFACES OF THE MISSISSIPPI RIVER BETWEEN CAIRO, ILL., AND CARROLLTON, LA.

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., June 17, 1885.

CAPTAIN: I have the honor to submit the following report upon the reduction of observations for determining elevations and slopes of high and low water surfaces of the Mississippi River between Cairo, Ill., and Carrollton, La.

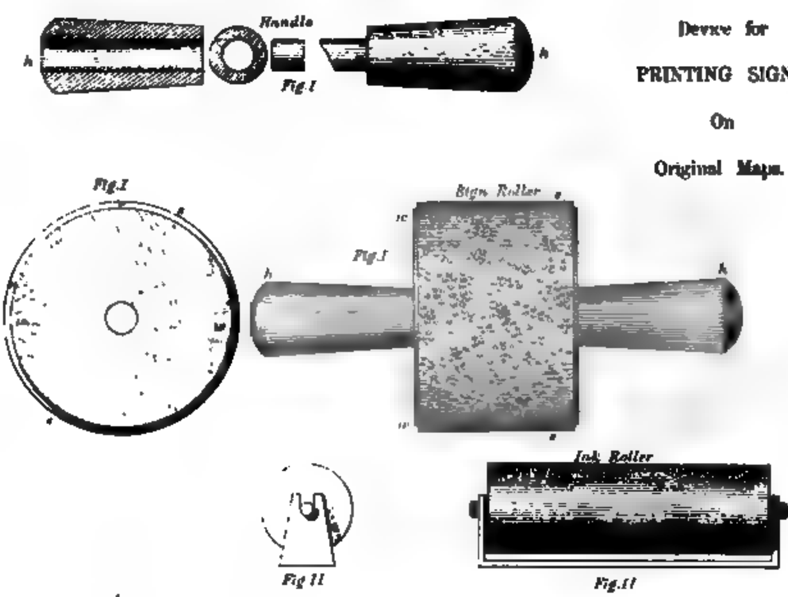
This report is accompanied by tables containing the results of the reduction of all data in this office on the subject. The reductions have been made by Mr. T. C. Thomas, except those for the high waters of 1883 and 1884, which have been made by Mr. John Ewens. All elevations in these tables refer to the Cairo Datum Plane, which is a plane 300 feet below the reading 9.16 feet on the Cairo gauge. Memphis Datum Plane, to which topographical elevations are referred, is 13.13 feet above Cairo Datum Plane. The preliminary elevation of Mean Gulf Level at Biloxi, Miss., is 21.26 feet.

The following table gives the elevations of the gauge zeros:

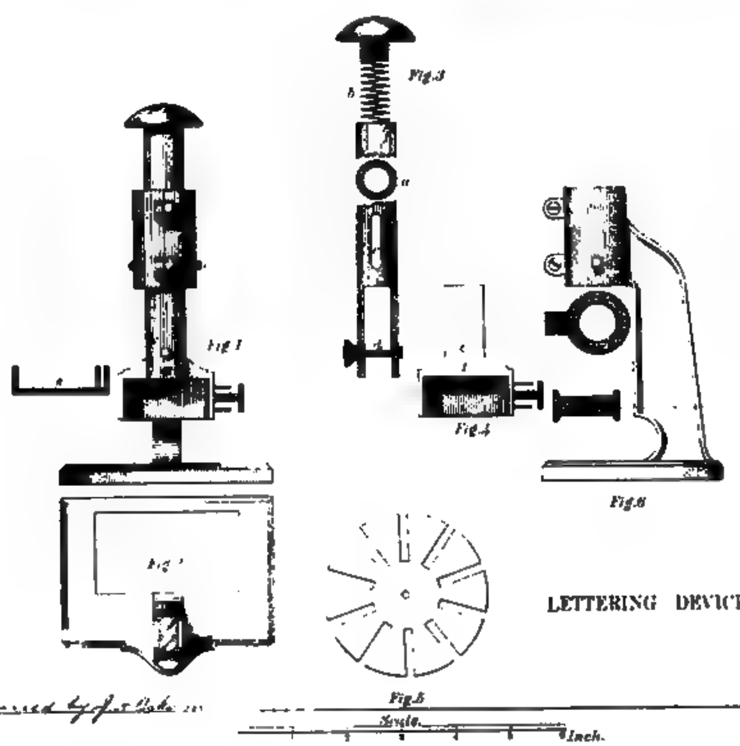
Gauge.	Elevation.	Gauge.	Elevation.
	Feet.		*Feet.*
Cairo, Ill	290.84	Greenville, Miss	108.[illegible]
Columbus, Ky	229.14	Lake Providence, La	89.62
New Madrid, Mo	276.04	Vicksburg, Miss	66.04
Cottonwood Point, Mo	250.62	Saint Joseph, La	52.74
Fulton, Tenn	228.55	Natchez, Miss	36.83
Memphis, Tenn	203.97	Red River Landing, La	22.55
Mhoon's Landing, Miss	181.48	Port Hickey, La	12.[illegible]
Helena, Ark	161.98	Baton Rouge, La	20.[illegible]
Saint Louis Landing, Ark	141.27	Plaquemine, La	21.[illegible]
Mouth White River, Ark	128.73	College Point, La	21.24
Arkansas City, Ark	116.35	Carrollton, La	20.91

The distances given in the tables are in miles from Cairo, Ill., and have been determined from the inch-to-the-mile series of maps published by the Mississippi River

Device for
PRINTING SIGNS
On
Original Maps.



LETTERING DEVICE.



sand
48

50

Commission. Each point of elevation has been located on these as near as possible, and the nearest tenth of a mile taken as the distance. The name of the nearest place is used to approximately locate the point.

All elevations of water surfaces have been given in the tables, however erroneous they may appear to be when compared with elevations above and below them, but in computing slope all elevations known to be doubtful have been omitted. The doubtful elevations are not in sufficient number to materially detract from the value of the tables, except in those of the low-water slope of 1883, where the number of erroneous elevations is quite large. These, with the large number of points for which there are no elevations at all, very materially diminish the value of the low-water slope for that year. This is the more unfortunate since that is the only low-water slope ever taken over the entire river from Cairo to Carrollton.

HIGH-WATER ELEVATIONS AND SLOPES.

In the following tables are given elevations of high waters for the years 1858, 1862, 1867, 1874, 1876, 1880, 1882, 1883, and 1884, but slopes have been computed for the last four years only, on account of the small number of elevations available for the earlier years. The elevations for high water of 1880 and of previous years, aside from those determined from gauge readings, were determined by a party in charge of Assistant Engineer Arthur Hider. This party commenced work at Cairo November 1, 1880, and reached Carrollton April 9, 1881, in the mean time being engaged on other work as well as determining high-water marks. The work was continued to Buras Settlement, 76 miles below Carrollton, but no lines of levels have been run over this portion of the river, and consequently no elevations are available. The marks were made permanent at the different points, generally by driving a large nail or small spike into a tree at the height of high water, blazing the tree, and cutting in the wood the figures denoting the year. A careful description of each of the marks was made in the note-books.

The elevations for high water of 1882 were determined by parties in charge of Assistant Engineers Hunter Stewart and J. H. Davis. Mr. Stewart commenced work at Cairo August 24, 1882, and continued work to Ashton Landing, La., 520 miles from Cairo, where he was taken sick December 13, 1882, and the work stopped. The work was taken up by Mr. Davis at Vicksburg, January 20, 1883, and completed to Carrollton April 5, 1883. The marks were made permanent in the same manner as those of 1880, and in a great number of cases are at the same localities as those of 1880.

The parties were supplied with postal cards on which were printed forms for recording how much the high water of 1883 was above or below the established marks of 1882. These cards were left with residents in the vicinity of the marks, with a request to make the necessary observation and forward the result to the office of the Commission. These requests were quite largely complied with, and the high water of 1883 has been determined from that of 1882 in this manner, aided by the gauge-readings. The high water of 1884 has been determined in the same manner. The elevations determined in this manner have, in the main, been satisfactory, but are not entitled to the same weight as those determined for the high waters of 1880 and 1882.

The following table contains the elevations of the several high waters at a few common points on the river:

Elevations of high waters.

Locality.	Distance.	1858.	1862.	1867.	1874.	1876.	1880.	1882.	1883.	1884.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Cairo	....	341.40	342.71	341.81	338.21	337.22	335.44	342.71	343.01	342.63
Columbus	21.2	329.77	330.92	330.44	....	....	326.31	331.93	332.42	332.22
Salmon's Landing	33.6	....	....	325.56	....	....	322.13	326.90	327.23	327.15
Morrisson's Landing	68.9	....	315.24	....	....	....	310.74	317.29	317.54	317.54
Cottonwood Point	123.3	288.68	288.68	288.09	....	....	286.00	288.18	288.47	287.96
Fulton	175.4	....	....	....	....	....	262.72	265.22	264.84	264.28
Memphis	230.3	238.13	238.42	238.82	237.97	238.05	237.38	239.12	238.72	238.12
Mhoon's Landing	275.8	....	....	....	....	....	217.58	221.28	221.68	220.36
Helena	306.5	206.58	208.37	207.79	207.77	206.82	205.66	209.17	208.88	208.98
Delta	314.4	203.86	....	....	203.34	203.10	201.89	204.39	203.97	....
White River	394.4	....	....	175.58	175.33	175.43	175.28	177.18	176.57	176.47
Riverton	399.6	172.34	173.32	171.49	172.45	172.78	172.34	174.48	174.06	173.98
Arkansas City	438.3	....	....	....	....	....	161.52	163.45	162.57	162.71
Greenville	478.5	151.00	....	147.92	148.92	149.28	148.41	149.72	148.40	149.10
Lake Providence	542.3	....	130.50	128.93	127.00	127.58	126.86	127.94	126.10	128.08
Vicksburg	599.2	112.94	117.14	115.06	111.74	110.94	109.19	114.79	109.84	115.04
Saint Joseph	647.7	....	....	....	....	....	94.04	96.87	93.87	97.65
Natchez	700.4	85.08	82.01	84.76	82.44	80.69	79.95	84.43	80.84	84.24
Red River Landing	765.3	....	....	70.18	70.85	69.26	67.90	72.35	68.86	70.96
Baton Rouge	833.3	54.57	56.17	....	56.21	53.46	53.26	56.02	55.15	56.27
Donaldsonville	885.4	....	48.35	....	48.29	....	45.28	47.27	47.27	47.88
Carrollton	957.0	36.01	36.81	....	36.61	33.61	35.16	35.86	36.31	36.51

LOW-WATER ELEVATIONS AND SLOPES.

The observations for determining low-water slope of 1880 were made by a party in charge of Assistant Engineer Arthur Hider, between October 8 and 20, 1880, and extend from Cairo to Commerce, Miss., a distance of 270 miles. These observations consisted in leveling from the water-surfaces to temporary bench-marks on the banks about 3 miles apart on the channel side of the river, the bench-marks being subsequently connected with the main line of levels. In all 101 points of elevation were taken, but of these 4 elevations proved erroneous, and for 2 points no elevations were obtained, leaving 95 points of elevation in 270 miles.

In reducing the observations, after the correct elevation of the water-surface at the time of observation has been obtained from the level notes, a correction has been applied to the elevation for oscillation or change of stage. The stage of the river at Cairo, on October 1, was 7.96 feet. The river rose slowly until the 8th when the gauge read 9.40 feet; it then fell slowly until October 15 when the gauge read 7 feet; it rose to 8.35 feet on the 17th, and then slowly fell till the end of the month. At Memphis the river rose slowly to 4.70 feet on the 10th, and then slowly declined. The river was practically stationary at Cairo, October 8; at New Madrid, October 9; at Cottonwood Point, October 10 (a. m.), at Fulton, October 10 (p. m.), and at Memphis October 11; and the stage indicated by the gauge readings on these dates has been assumed as the stage to which the observations should be reduced. The reference stage is really the crest of a small rise, and corresponds to the stage of 9.40 on the Cairo gauge supposed to move down-stream at the rate of 3¼ miles per hour.

The difference between the reference stage and the stage at time of observation has been applied as a correction to the observed elevation. The stage at time of observation has been determined by the gauge readings, it being assumed that the changes at points between the gauges were proportional to their distances from the gauges. An interpolation has also been made for the change of stage between the time of observation and the time of gauge reading. The corrections for oscillation are given in the tables, the maximum correction being 1.53 feet.

The observations for determining low-water slope of 1882 were made by a party in charge of Assistant Engineer J. H. Davis, between November 1 and 30, 1882, and extended from Commerce, Miss., to Natchez, Miss., a distance of 431 miles. These observations, like those made in 1880, consisted in leveling from the water-surface to temporary bench-marks on the banks. The points of observation were distributed with reference to the natural features of the river. An effort was made to include either a straight reach or uniform bend between consecutive points. Proximity to some permanent bench-mark was also sought, this being, however, a matter of secondary importance. In all 119 points of observation were taken, but of these 8 were not connected with the main line of levels, leaving 111 points in a distance of 431 miles. There were no elevations found to be erroneous.

During the time these observations were in progress, the stage of river changed very little, there being a slight rise in the lower portion the latter part of the month. The elevations of water-surfaces have been corrected for change of stage, the stage to which they have been reduced corresponding to that of the minimum gauge readings at Mhoon's Landing, Miss., and Natchez, Miss. The minimum gauge reading at Mhoon's Landing was 6.90 feet on October 23, and at Natchez was 9.70 on November 6. This reference stage corresponds to the reading 4.47 feet on the Memphis gauge. A lower stage was reached at Mhoon's Landing that year, but it had no relation to the stage at which the work was done.

The reference stage at gauges intermediate between Mhoon's Landing and Natchez has been determined in the following manner: It has been assumed that the rate of travel of the minimum stage was uniform from Mhoon's Landing to Natchez, and the date of its arrival at any gauge computed on this assumption. The gauge reading at that time was taken as the stage of reference at each gauge. The dates at all the gauges correspond to the times of minimum readings, except at mouth of White River and Arkansas City, where the readings were affected by a rise out of the White and Arkansas rivers. The difference between the reference stage and the stage at time of observation has been applied as a correction to the observed elevation at any point, the stage at time of observation being determined in the same manner as for the low-water slope of 1880. The maximum correction for oscillation is 4.95 feet.

The observations for determining low-water slope of 1883, were made by a party in charge of Assistant Engineer John Ewens on the steamer Patrol between October 11 and 31, 1883, and extend from Cairo to New Orleans, a distance of 963 miles. Observations were also made between Saint Louis and Cairo, but the temporary bench-marks have not been connected with the main line of levels. The river while this work was in progress was rising throughout its length, the minimum stage having been passed. The minimum gauge reading at Cairo was 4.70 feet on September 30, at Memphis 1.90 feet on October 2, at Vicksburg, 2.90 feet on October 6, and at Carrollton 0.50 foot on October 15.

The observations, like those of 1880 and 1882, consisted in leveling from the water surface to temporary bench-marks on the banks; but in doing this a long rod graduated to feet and attached to the jack-staff of the steamer was used at nearly all the points. This rod was provided with a special apparatus at the foot for connecting with the water-surface. The points of elevation were chosen at the head and foot of bends, so as to include between them either bends or crossings. The object of this arrangement was to give the slope on the crossings and in the bends separately, but the value of this arrangement is partially destroyed by the number of points for which there are no elevations. In all 279 points were established, but for 86 of these no elevations have been obtained, and for 12 the elevations were erroneous and have been rejected. No work was done by this party along the Plum Point Reach, but bench-marks were established by a topographical party.

The observed elevations of water-surfaces have been reduced to a stage of river corresponding to the minimum gauge reading at Cairo for the year. Were there no tributaries below Cairo this stage in traveling down the river would arrive at each gauge at the time of minimum reading on the gauge, and the time of its occurrence would be indicated by the gauge record. But the larger tributaries affect considerably the readings of gauges near their mouths, and this method is not applicable. The time when the reference stage passed the several gauges has been determined in the following manner: The distance of each gauge from Cairo and the days of the month from September 30 to October 15 were set off along two co-ordinate axes. The whole distance from Cairo to Carrollton was divided into stretches by the terminal gauges and such intermediate gauges as were not liable to be greatly affected by the tributaries. The Greenville and Port Hickey gauges were selected as probably fulfilling the above condition. A line was drawn from the point on the Cairo line representing the time of minimum reading to the point on the Greenville line representing the time of its minimum reading. Assuming the rate of travel of the reference stage to be uniform from Cairo to Greenville, this line will intersect each gauge in the point representing the time at which the reference stage passed that gauge. The other stretches were treated in the same manner. These lines intersect the gauges at or very near the times of minimum readings, the maximum divergence being at Red River Landing where the time of reference stage is two days after the time of minimum reading, and the stage 0.35 foot above the minimum. The rate of travel of reference stage varied considerably, being 119 miles per day from Cairo to Greenville, 47 miles per day from Greenville to Port Hickey, and 40 miles per day from Port Hickey to Carrollton.

The reference stage being determined, the corrections for oscillation have been determined in the same manner as for 1880 and 1882. It will be seen from the tables that the correction for oscillation varies considerably in the length of the river, being 3.15 feet at Cairo, 2.07 feet at Memphis, 6.05 feet at Arkansas City, 4.75 feet at Lake Providence, 5.76 feet at Vicksburg, 5.56 feet at Red River Landing, and 1.30 feet at Carrollton.

Very respectfully, your obedient servant,

L. L. WHEELER,
In Charge Computing Division.

Capt. THOMAS TURTLE,
Secretary Mississippi River Commission.

Tables of high and low water elevations and slopes, Mississippi River.

HIGH-WATER MARKS OF 1858.

Locality of high-water marks.	Bank.	Distance from Cairo.	Elevation, Cairo datum.	Fall between high-water marks.	Distance between high-water marks.	Slope, feet per mile.	Date high water.	Remarks.
		Miles.	*Feet.*	*Feet.*	*Miles.*			
Cairo, Ill			341.40					
Widow Mercer's	R.	6.3	338.59					
Columbus, Ky	L.	21.2	339.77					
Above Stewart's	R.	89.0	303.62					
Wilkes, Chute of Islands 16 and 17	R.	117.7	289.52					
Cottonwood Point	R.	123.3	288.68					
Ashport, Tenn	L.	153.3	273.78					
Memphis, Tenn	L.	230.3	238.13					
Helena, Ark	R.	306.5	206.58					
Delta, Miss., opposite	R.	315.5	203.86					
Riverton	L.	399.6	172.84					
Greenville	L.	478.5	151.00					
Vicksburg	L.	599.2	112.94					
Natchez	L.	700.4	85.08					
Baton Rouge	L.	833.3	54.57					
Carrollton	L.	957.0	36.01				May 10	

HIGH-WATER MARKS OF 1862.

Locality of high-water marks.	Bank.	Distance from Cairo.	Elevation, Cairo datum.	Fall between high-water marks.	Distance between high-water marks.	Slope, feet per mile.	Date high water.	Remarks.
Cairo, Ill			342.71					
Columbus	L.	21.2	330.92					
Hickman	L.	36.0	325.86					
Morrison's Landing	R.	68.9	315.24					
Brownell's Landing	R.	75.0	312.20					
Gayoso	R.	105.7	297.23					
Wilkes, Chute of Islands 16 and 17	R.	117.7	289.52					
Cottonwood Point	R.	123.3	286.68					
Plum Point	L.	164.2	272.92					
Memphis, Tenn	L.	230.8	238.42					
Harbert's Landing, 1 mile below	L.	293.0	212.61					
Helena, Ark	R.	306.6	208.37					
Riverton (below)	L.	399.6	173.32					
Llewellyn	R.	463.5	154.66					
Lake Providence	R.	542.3	130.50					
Vicksburg	L.	599.2	117.14				April 27	
Opposite Warrenton	R.	606.7	112.28					
Natchez	R.	700.4	82.01					
Baton Rouge	L.	833.3	56.17					
Donaldsonville	R.	885.4	48.35					
Carrollton	L.	957.0	36.81					

HIGH-WATER MARKS OF 1867.

Locality of high-water marks.	Bank.	Distance from Cairo.	Elevation, Cairo datum.	Fall between high-water marks.	Distance between high-water marks.	Slope, feet per mile.	Date high water.	Remarks.
Cairo, Ill			341.81				Mar. 21	
Head of Island No. 2	L.	12.0	335.58					tas to year.
Columbus	L.	21.2	330.44					
Salmon's Landing	L.	33.6	325.56					
Hickman	L.	36.0	324.13					
Head of Island No. 8	L.	41.8	321.93					
Lester	L.	53.6	317.46					
Donaldson's Point	R.	59.8	317.28					
Brownell's Landing	R.	75.0	311.54					
Gayoso	R.	105.7	294.48					
Wilkes, Chute of Islands 16 and 17	R.	117.7	289.69					
Above Cottonwood	[illegible]	120.8	288.40					
Cottonwood Point (Garrett's House)	R.	122.4	288.09					
Ward's, Ark	R.	148.2	275.93					

Table of high and low water elevations and slopes, Mississippi River—Continued.

HIGH-WATER MARKS OF 1867—Continued.

Locality of high-water marks.	Bank.	Distance from Cairo.	Elevation, Cairo datum.	Fall between high-water marks.	Distance between high-water marks.	Slope, feet per mile.	Date high water.	Remarks.
		Miles.	*Feet.*	*Feet.*	*Miles.*			
Above Centennial Cut-off	....	199.6	255.05					
Below △ Hearn	L.	211.9	245.19					
Memphis, Tenn	L.	230.3	238.82					
Harbert's Landing	L.	293.0	212.10					
Helena	R.	306.5	207.79					
White River Landing	R.	394.4	175.53					
Riverton	L.	399.6	171.49					
Greenville	L.	478.5	147.92					
Lake Providence	R.	542.3	128.93					
Vicksburg	L.	599.2	115.08					
Opposite Yucatan	R.	629.5	102.44					
Natchez	R.	700.4	84.76					
Fairview	R.	727.6	75.17					
Above Bougere	R.	737.2	76.34					Not well defined.
Red River Landing	R.	765.3	70.18					

HIGH-WATER MARKS OF 1874.

Locality of high-water marks.	Bank.	Distance from Cairo.	Elevation, Cairo datum.	Fall between high-water marks.	Distance between high-water marks.	Slope, feet per mile.	Date high water.	Remarks.
Cairo, Ill			338.21				Apr. 26	
Memphis, Tenn	R.	230.3	237.97				May 2	
Helena	R.	306.5	207.77				May 11	
Delta	L.	314.4	203.34					
Friar's Point	L.	319.0	202.19					
Australia Landing	L.	369.7	183.36					
Henrico Landing	R.	383.2	179.11					
White River Landing	R.	394.4	175.33					
Riverton	L.	399.6	172.45					
Catfish Point	L.	423.2	165.71					
Woodstock	L.	464.2						
Greenville	L.	478.6	146.92					
Lake Providence	R.	542.3	127.00				Mar 23	
Duckport	R.	589.7	115.67					
Vicksburg	L.	599.2	111.74				May 2–5	
Natchez	L.	700.4	82.44				Apr. 20	
Fairview	R.	727.6	76.27					
Cerro Gordo	L.	733.9	75.62					
Above Bougere	R.	737.2	76.34					Not well defined.
Red River Landing	R.	765.3	70.85				Apr. 16	
Brunette Point	R.	779.5	67.18					
Waterloo, La	R.	805.2	62.08					
Grossman's Landing	R.	822.1	58.92					
Lobdell's Landing	R.	825.5	56.80					
Baton Rouge	L.	833.3	56.21				Apr. 16	
Missouri Plantation	R.	830.6	55.10					
Hollywood	L.	842.0	54.33					
Forlorn Hope	L.	858.0	53.41					
Point Pleasant	R.	863.4	51.83					
Cora Plantation	R.	868.8	50.31					
Ashland	L.	878.2	49.27					
Donaldsonville	R.	885.4	48.29					
Carrollton	L.	957.0	36.61				Apr. 16	

HIGH-WATER MARKS OF 1876.

Locality of high-water marks.	Bank.	Distance from Cairo.	Elevation, Cairo datum.	Fall between high-water marks.	Distance between high-water marks.	Slope, feet per mile.	Date high water.	Remarks.
Cairo, Ill	...		337.22				Apr. 6	
Below Island No. 29	L.	160.6	270.00					
Above Centennial Cut-off	..	199.6	255.05					
Memphis	L.	230.3	238.05				Apr. 8	
Helena	R.	306.5	206.82				Apr. 18	
Delta	L.	314.4	203.10					
Australia	L.	369.7	183.04					
Henrico Landing	R.	383.2	178.71					

Tables of high and low water elevations and slopes, Mississippi River—Continued.

HIGH-WATER MARKS OF 1884—Continued.

Locality of high-water marks.	Banks.	Distance from Cairo.	Elevation, Cairo datum.	Fall between high-water marks.	Distance between high-water marks.	Slope, feet per mile.	Date high water.		Remarks.
		Miles.	*Feet.*	*Feet.*	*Miles.*				
Port Hickey, La	L.	810.0	61.100	9.860	44.7	.221	Mar.	29	U. S. gauge.
Baton Rouge, La	L.	833.3	56.270	4.830	23.3	.207	Mar.	24	U. S. gauge.
Missouri Plantation, La	R.	839.6	55.544	0.726	6.3	.115	Mar.	25	
Woodstock Plantation, La.	R.	844.6	54.224	1.320	5.0	.264	Mar.	24	
Plaquemine, La	R.	853.5	52.660	1.564	8.9	.176	Mar.	24	U. S. gauge.
Brode's Landing, La	R.	854.8	52.488	0.172	1.3	.132	Mar.	24	
Bayou Goula, La	R.	866.1	50.930	1.558	11.3	.137	Mar.	24	
Ashland, La	L.	878.2	49.355	1.575	12.1	.130	Mar.	24	
Donaldsonville, La	R.	885.4	47.327	2.028	7.2	.281	Mar.	23	
Colombia Landing, La	L.	897.7	45.654	1.673	12.3	.136	Mar.	24	
College Point, La	L.	903.0	45.290	0.364	5.3	.069	Mar.	24	U. S. gauge.
Belmont Plantation, La	L.	906.8	44.646	0.644	3.8	.169	Mar.	1–10	
Mount Airy Plantation, La	L.	915.0	43.085	1.561	8.2	.190	Mar.	24	
Carrollton, La	L.	957.0	36.510	6.575	42.0	.156	Mar.	18	U. S. gauge.

LOW-WATER SLOPE OF 1880.

No. of station.	Locality of station.	Bank.	Distance from Cairo	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Time of observation. Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
1	Cairo, Ill			300.20		300.20			*	Oct. 8	2 p. m.
2	Three States Ferry	L.	2.4	299.62	+.02	299.64	0.56	2.4	0.233		4 p. m.
3	Island, No. 1	L.	6.0	298.96	.07	299.03	.61	3.6	.169	Oct. 9	7 a. m.
4	△ Beckwith	R.	8.6	298.13	.07	298.20	.83	2.6	.319	Oct. 9	9 a. m.
5	△ Davidson	L.	9.1	297.65	.08	297.73	.47	0.5	.940		9 a. m.
6	△ Island No. 2	L.	12.4	297.39	.08	297.47	.26	3.3	.079		11 a. m.
7	△ Tarr	R.	15.1	296.96	.07	297.03	.44	2.7	.163		12 m.
8	△ Cannon	R.	18.0	296.32	.08	296.40	.63	2.9	.217		2 p. m.
9	Columbus, Ky	L.	21.2	295.90	.06	295.96	.44	3.2	*.138		3 p. m.
10	△ Thorn	L.	23.0	295.09	.04	295.13	.83	1.8	.461		4 p. m.
11	△ Muscavally	L.	25.2	293.90	.04	293.94	1.19	2.2	.541		5 p. m.
12	△ Wiggins	L.	27.5	292.43	.02	292.45	1.49	2.3	.648	Oct. 10	8 a. m.
13	△ Ferris Landing	R.	28.9	291.78	.03	291.81	.64	1.4	.457		9 a. m.
14	△ Parker	R.	32.0	290.51	.04	290.55	1.26	3.1	.406		10 a. m.
15	Above Salmon's	L.	33.7	289.90	.05	289.95	.60	1.7	.353		11 a. m.
16	△ Hickman	L.	36.2	289.50	.05	289.55	.40	2.5	.160		11 a. m.
17	△ Kaiser	L.	38.7	289.39	.06	289.45	.10	2.5	.040		1 p. m.
18	△ French's Point	L.	41.6	288.55	.10	288.65	.80	2.9	.276		3 p. m.
19	△ St. James	R.	44.5	287.72	.10	287.82	.83	2.9	.286		3 p. m.
20	Below St. James Bayou	R.	46.8	286.81	.11	286.92	.90	2.3	.391		4 p. m.
21	△ Mitchum	L.	50.0	286.66	.13	286.79	.13	3.2	.041		5 p. m.
22	Above △ Lester	L.	53.6	285.88	.27	286.15	.64	3.6	.178	Oct. 11	8 a. m.
23	△ Birdsall	R.	55.6	284.85	.27	285.12	1.03	2.0	.515		9 a. m.
24	Below △ Tennessee	L.	59.5	284.52	.25	284.77	.35	3.9	.090		2 p. m.
25	△ Bryant's Point	R.	62.9	282.86	.28	283.14	1.63	3.4	0.479	Oct. 11	4 p. m.
26	Below △ Everett	L.	66.1	281.35	.28	281.63	1.51	3.2	.472		6 p. m.
27	Morrison's Landing	R.	68.9	280.65	.25	280.90	.73	2.8	*.261		4 p. m.
28	Below New Madrid	R.	71.1	279.01	.46	279.47	1.43	2.2	.650	Oct. 12	8 a. m.
29	△ Bob Watson	L.	74.7	277.92	.45	278.37	1.10	3.6	.306		8 a. m.
30	Below △ Compromise	L.	77.3	276.02	.47	276.49	1.88	2.6	.723		9 a. m.
31	△ Point Pleasant	R.	80.0	274.00	.46	274.46	2.03	2.7	.752		10 a. m.
32	Above △ Gold	R.	82.7	272.97	.48	273.45	1.01	2.7	.374		12 m.
33	Tiptonville	L.	85.3	270.52	.47	270.99	2.46	2.6	.946		12 m.

* United States gauge.

Tables of high and low water elevations and slopes, Mississippi River—Continued.

LOW-WATER SLOPE OF 1889—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
34	Below △ Stewart	R.	90.1	268.67	+.77	269.44	1.55	4.6	.338	Oct. 13	12 m.
35	Near △ Solitude	R.	93.3	267.74	.50	268.24	1.20	3.2	.375	Oct. 12	4 p. m.
36	Below △ Base	L.	96.8	265.60	.52	266.12	2.12	3.5	.606		6 p. m.
37	△ Dr Smith	L.	99.6	263.29	.78	264.07	2.05	2.8	.732	Oct. 13	10 a. m.
38	Above Gayoso	L.	102.5	264.64	.82	265.46		2.9	(†)		11 a. m.
39	Gayoso	R.	105.6	262.63	.80	263.49	.58	3.1	.097		2 p. m.
40	△ Warden	R.	107.2	260.59	1.16	261.75		1.6		Oct. 14	10 a. m.
41	Near △ Caruthersville	R.	110.3	261.28	1.17	262.45	1.04	3.1	‡.226		10 a. m.
42	△ Linwood	L.	113.8	259.16	1.24	260.40	2.05	3.5	.586		12 m.
43	Booth's Point	L.	117.5	257.19	1.26	258.45	1.95	3.7	.527		12 m.
44	△ Bell's Point	L.	120.3	254.86	1.28	256.14	2.31	2.8	.825		2 p. m.
45	Cottonwood Point	R.	123.1	254.47	1.36	255.83	.31	2.8	*.111		3 p. m.
46	Lintdale	R.	125.3	253.50	1.32	254.82	1.01	2.2	.459		5 p. m.
47	△ Arkansas	R.	128.9	254.64	1.30	255.94		3.6	(§)		5 p. m.
48	△ Mrs. H	R.	131.3	252.29	1.27	253.56	1.26	2.4	.210		6 p. m.
49	Wright's Point	R.	133.7	248.96	1.53	250.49	3.07	2.4	1.279	Oct. 15	8 a. m.
50	△ Hale's Point	L.	136.0	248.52	1.51	250.03	.46	2.3	.200		8 a. m.
51	Near △ Nebraska	L.	138.3	248.16	1.49	249.65	.38	2.3	.165		9 a. m.
52	△ Buckner	R.	140.2	247.72	1.47	249.19	.46	1.9	.242		9 a. m.
53	Above △ Barfield	R.	141.7	247.37	1.45	248.82	.37	1.5	.247		10 a. m.
54	△ K. C. B	L.	144.8		1.43			3.1	(‖)		12 m.
55	Near △ Forked Deer	L.	146.4	246.26	1.41	247.67	1.15	1.6	¶.244		12 m.
56	Below △ Bowen	R.	149.3	247.63	1.39	249.02		2.9			2 p. m.
57	△ Daniel's Point	R.	152.0	245.19	1.42	246.61	1.06	2.7	.180		3 p. m.
58	Ashport, Tenn	L.	153.3	244.77	1.36	246.13	.48	1.2	.369		2 p. m.
59	Johnson's Landing	L.	156.2	244.19	1.35	245.54	.59	2.9	.203		4 p. m.
60	Below △ Fletcher	R.	157.5	242.96	1.33	244.29	1.25	1.3	.961		4 p. m.
61	Two miles below △ Fletcher	R.	159.7	241.55	1.33	242.88	1.41	2.2	.641		5 p. m.
62	△ Elmot	R.	161.4	241.05	1.41	242.46	.42	1.7	.247	Oct. 16	7 a. m.
63	Plum Point	L.	164.2	238.74	1.41	240.15	2.31	2.8	.825		8 a. m.
64	Below Osceola	R.	165.7	238.71	1.41	240.12	.03	1.5	.020		9 a. m.
65	Below Bullerton T. H	R.	170.5	234.76	1.41	236.17	3.95	4.8	.823		10 a. m.
66	Fulton	L.	175.4	234.32	1.41	235.73	.44	4.9	*.090		11 a. m.
67	△ Lee	L.	176.9	233.60	1.45	235.05	.68	1.5	.453		4 p. m.
68	Near foot of Island No. 34	R.	179.8	231.60	1.45	233.05	2.00	2.9	.690		4 p. m.
69	Below △ Pierce	R.	182.5	228.70	1.45	230.15					5 p. m.
	Mean		182.6			230.32	2.73	2.8	.975		
70	Randolph	L.	182.7	229.05	1.45	230.50					6 p. m.
71	Richardson's Landing	L.	185.8	228.78	1.41	230.19	.13	3.2	.041	Oct. 17	8 a. m.
72	Near △ Lanier	R.	188.4	227.51	1.41	228.92	1.37	2.6	.488		9 a. m.
73	△ Golden Lake	R.	191.5	225.12	1.41	226.53	2.39	3.1	0.771	Oct. 17	9 a. m.
74	△ Powers	R.	193.7	223.96	1.42	225.38	1.15	2.2	.523		10 a. m.
75	△ Pecan Point	R.	195.8	223.36	1.41	224.77	.61	2.1	.290		11 a. m.
76	△ Wright	L.	198.0	222.57	1.41	223.98	.79	2.2	.359		12 m.
77	P. B. M. No. 53	L.	201.2	221.03	1.41	222.44	1.54	3.2	.481		4 p. m.
78	Head of Centennial Cut-off	L.	203.3	220.82	1.38	222.20	.24	2.1	.114		5 p. m.
79	△ Bateman	L.	207.5	217.77	1.42	219.19	3.01	4.2	**.717	Oct. 18	8 a. m.
80	Head of Fogleman's Chute	R.	207.9	217.53	1.41	218.94	3.26	4.6	.709		8 a. m.
							[.69	3.6	††.192		
81	△ Hearn	L.	211.1	217.08	1.42	218.50	0.44	3.3	.133		9 a. m.
82	△ Bradley's Landing	R.	214.7	214.24	1.42	215.66	2.84	3.6	.789		10 a. m.
83	△ Ferguson	R.	217.9	212.40	1.42	213.82	1.84	3.2	.575		11 a. m.
84	△ Walt	R	220.3	210.29	1.41	211.70	2.12	2.4	.883		12 m.
85	△ Mort sey	L	224.1	209.17	1.41	210.58	1.12	3.8	.295		2 p. m.
86	Below Mound City	R	226.9	208.14	1.41	209.55	1.03	2.8	.368		3 p. m.
87	Memphis	L.	230.3	207.96	1.41	209.37	.18	3.4	*.053		6 p. m.
88	3 miles below Memphis	R	235.0	207.31	1.12	208.43	.94	4.7	.200	Oct. 19	12 m.
89	Opposite Foot Vice-President's Island	R.	236.7	205.90	1.15	207.05	1.38	1.7	.812		12 m.
90	Dismal Point	R.	239.2	203.45	1.16	204.61	2.44	2.5	.976		12 m.
91	Below △ Easley	L	241.9	201.48	1.16	202.64	1.97	2.7	.730		2 p. m.
92	△ Watson	L.			1.18						3 p. m.

* United States gauge.
† As to elevation of reference B. M.
‡ B. M. connected with in 1883-'84.
§ Reference B. M. a stake marking △ Arkansas.
‖ Elevation of reference B. M. undetermined.
¶ W. S. referred to a P. B. M.
** In Bateman's Bend.
†† Slope through Bateman's Bend, between stations 78 and 81.

Tables of high and low water elevations and slopes, Mississippi River—Continued.

LOW WATER SLOPE OF 1880—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W's Cairo datum.	Correction for change of gauge.	Corrected elevation of W's Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Time of observation. Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
93	Above Scanlan's	L.	246.8	198.79	+1.17	199.96	2.68	4.9	.547	....	4 p. m.
94	Below Scanlan's	R.	249.3	197.47	1.18	198.65	1.31	2.5	.524	....	5 p. m.
95	Above Pickering's	R.	251.6	197.15	1.06	198.21	.44	2.3	.191	Oct. 20	8 a. m.
96	Norfolk Landing	L.	253.8	196.46	1.05	197.51	.70	2.2	.318	....	8 a. m.
97	Star Landing	L.	258.2	195.35	1.05	196.40	1.11	4.4	.252	....	9 a. m.
98	Above Bennett's	R.	261.4	194.69	1.06	195.75	.65	3.2	.203	....	10 a. m.
99	Bennett's Landing	L.	263.0	193.46	1.06	194.52	1.23	1.6	.769	....	11 a. m.
100	Excelsior Landing	R.	266.5	192.44	1.07	193.51	1.01	3.5	.289	....	12 m.
101	Commerce	L.	269.8	190.91	1.08	191.99	1.52	3.3	.461	....	1 p. m.

LOW-WATER SLOPE OF 1892.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W's Cairo datum.	Correction for change of gauge.	Corrected elevation of W's Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Time of observation. Hour.
1	Commerce Landing	L.	270.0	191.16	—0.72	190.44	.....	.....	.....	Nov. 1	4 p. m.
2	Campbell's Landing	R.	272.4	189.98	.78	189.20	1.24	2.4	0.517	Nov. 2	8 a. m.
3	Mhoon's Landing	L.	276.0	189.39	.80	188.59	.61	3.6	.169	....	11 a. m.
4	Bordeaux Landing	L.	278.5	187.55	.80	186.75	1.84	2.5	.736	....	2 p. m.
5	Bordeaux Chute	L.	283.0	184.83	.81	184.02	2.73	4.5	.607	....	4 p. m.
6	O. K. Landing	L.	290.1	180.26	.82	179.44	4.58	7.1	.645	Nov. 3	9 a. m.
7	Harbert's Landing	L.	293.4	180.04	.81	179.23	.21	3.3	.064	....	12 m.
8	Dr. Horner's	R.	299.3	.....	.79	.....	.....	.....	.....	....	4 p. m.
9	Helena Island	L.	302.2	.....	.80	.....	.....	.....	.....	Nov. 4	6 a. m.
10	Trotter's Landing	L.	303.5	172.61	.80	171.81	7.42	10.1	.735	....	9 a. m.
11	Helena, Ark	R.	306.2	172.53	.79	171.74	.07	2.7	*.026	....	6 a. m.
12	Williams Landing	R.	311.0	171.17	.74	170.43	1.31	4.8	.273	....	5 p. m.
13	Delta Landing	L.	314.5	168.69	.72	167.97	2.46	3.5	.703	Nov. 5	9 a. m.
14	Craig's Landing	R.	317.0	166.94	.69	166.25	1.72	2.5	.689	....	12 m.
15	Archie Lucas Place	L.	320.8	166.73	.65	166.08	.17	3.8	.044	....	2 p. m.
16	Opposite Miller's Point	R.	324.2	166.58	.62	165.96	.12	3.4	.035	....	4 p. m.
17	Allison's Landing	R.	328.1	.....	.64	.....	.....	.....	.....	Nov. 6	8 a. m.
18	Opposite Island No. 62	L.	330.2	.....	.61	.....	.....	.....	.....	....	10 a. m.
19	Modoc Landing	R.	335.0	162.55	.53	162.02	3.94	10.8	.365	....	12 m.
20	Robson's Landing	L.	340.0	160.59	.46	160.13	1.89	5.0	.378	....	3 p. m.
21	Jackson's Point	L.	342.6	.....	.42	.....	.....	.....	.....	....	4 p. m.
22	Offut's or Ludlow's	R.	347.1	159.41	.37	159.04	1.09	7.1	.154	Nov. 7	8 a. m.
23	Saint Louis Landing	R.	349.4	158.34	.33	158.01	1.03	2.3	.448	....	12 m.
24	Sunflower Landing	L.	352.5	156.55	.27	156.28	1.73	3.1	.558	....	12 m.
25	Malone's Landing	L.	356.2	155.91	.22	155.69	.59	3.7	0.159	Nov. 7	2 p. m.
26	Pushmataha	L.	359.3	155.49	.20	155.29	.40	3.1	.129	....	4 p. m.
27	Foot of Island No. 68	R.	364.1	151.86	.22	151.64	3.65	4.8	.760	Nov. 8	7 a. m.
28	Beith's Landing	R.	366.3	151.74	.21	151.53	.11	2.2	.050	....	10 a. m.
29	Australia	L.	369.6	149.99	.20	149.79	1.74	3.3	.527	....	11 a. m.
30	Laconia	R.	373.4	148.87	.19	148.68	1.11	3.8	.292	....	1 p. m.
31	Head of Island No. 71	R.	376.2	.....	.18	.....	.....	.....	.....	....	3 p. m.
32	Maysonia Landing	L.	377.8	147.23	.18	147.05	1.63	4.4	.370	....	4 p. m.
33	Antler's	L.	381.6	146.61	.23	146.38	.67	3.8	.176	Nov. 9	8 a. m.
34	Caswell Place	R.	386.7	142.63	.22	142.41	3.97	5.1	.779	....	10 a. m.
35	McGehee's Landing	L.	391.1	140.58	.21	140.37	2.04	4.4	.464	....	12 m.
36	Terrene	L.	394.3	140.41	.....	.....	.....	.....	.....	....	4 p. m.
	Mean	..	394.4	140.44	.20	140.24	.13	3.3	.039	....	
37	Cummdysville	R.	394.4	140.47	.....	.....	.....	.....	.....	Nov. 10	7 a. m.
38	Rosedale	L.	398.2	139.74	.20	139.54	.70	3.8	.184	....	10 a. m.
39	Below Napoleon	R.	403.1	138.72	.20	138.52	1.02	4.9	.208	....	12 m.
40	Below Prentiss	L.	404.2	138.59	.20	138.39	.13	1.1	.118	....	1 p. m.
41	Below Ozark Island	R.	409.6	.....	.20	.....	.....	5.4	.....	....	3 p. m.
42	Caulk's Landing	R.	413.0	136.53	.20	136.33	2.06	8.8	.234	....	5 p. m.
43	Bolivar	L.	417.3	132.97	.20	132.77	3.56	4.3	.828	Nov. 11	7 a. m.
44	Cat Fish Point	L.	423.2	131.23	.20	131.03	1.74	5.9	.295	....	9 a. m.
45	Cypress Creek	R.	426.5	130.12	.20	129.92	1.11	3.3	.336	....	12 m.
46	Chicot City	R.	431.8	129.50	.21	129.29	.63	5.3	.119	....	1 p. m.
47	Mound Place	L.	435.7	127.38	.22	127.16	2.13	3.9	.546	....	3 p. m.
48	Wilkerson's Landing	L.	436.8	126.32	.23	126.09	1.07	1.1	.973	....	5 p. m.
49	Arkansas City	R.	439.1	126.21	.20	126.01	.08	2.3	0.035	Nov. 11	12 m.
50	Near Eunice	R.	442.5	126.10	.38	125.72	.29	3.4	.085	Nov. 12	3 p. m.
51	Offutt's Landing	L.	445.4	125.63	.40	125.23	.49	2.9	.169	....	4 p. m.
52	Gaine's Landing	R.	450.2	124.66	.58	124.08	1.15	4.8	.240	Nov. 13	8 a. m.

* United States gauge.

Tables of high and low water elevations and slopes, Mississippi River—**Continued.**

LOW-WATER SLOPE OF 1882—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Time of observation. Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
53	Near Point Comfort	R.	453.6	123.89	—.59	123.30	.79	3.6	.217		10 a. m.
54	Shadyside	L.	457.4	123.00	.61	122.39	.91	3.6	.253		12 m.
55	Tarpley Plant	L.	461.5	121.44	63	120.81	1.58	4.1	.385		2 p. m.
56	Lewellyn, Ark	R.	464.7	121.28	64	120.64	.17	3.2	.053		5 p. m.
57	Luna, Ark	R.	467.5	120.04	.81	119.23	1.41	2.8	.504	Nov. 14	7 a. m.
58	Opposite Point Chicot	L.	475.8	118.88	.82	118.06	1.17	8.3	.141		10 a. m.
59	Greenville	L.	478.5	117.86	.85	117.01	1.05	2.7	.389		1 p. m.
60	A. Jack	L.	481.7	117.43	86	116.57	.44	3.2	.138		4 p. m.
61	Leland Plant	R.	483.5	116.30	87	115.43	1.14	1.8	.633		5 p. m.
62	Vaucluse Landing	R.	487.1	115.77	.96	114.79	.64	3.6	.178	Nov. 15	7 a. m.
63	Sunnyside Landing	R.	490.0	114.32	.98	113.34	1.45	2.9	.500		9 a. m.
64	Walnut Point Landing	L.	494.5		.97						10 a. m.
65	Lake Port Landing	L.	496.1	113.22	98	112.24	1.10	6.1	.180		12 m.
66	Glenora, Miss	L.	499.5	112.77	.99	111.78	.46	3.4	.135		2 p. m.
67	Longwood	L.	502.1	112.28	1.01	111.27	.57	2.6	.196		4 p. m.
68	Rosebank	R.	507.8	109.97	1.00	108.97	2.30	5.7	.403		5 p. m.
69	Near Leota Landing	L.	513.0	108.79	1.20	107.59	1.38	5.2	.265	Nov. 16	8 a. m.
70	Carolina Landing	L.	517.0	107.98	1.21	106.77	.82	4.0	.205		9 a. m.
71	Ashton Landing	R.	520.5	107.68	1.22	106.46	.31	3.5	.089		11 a. m.
72	Near Pilcher's Landing	R.	523.0	106.57	1.24	105.33	1.13	2.5	.452		12 m.
73	Pitman's Landing	R.	526.0	105.08	1.26	103.82	1.51	3.0	0.503	Nov. 16	3 p. m.
74	Wilson's Point	R.	531.3	104.06	1.46	102.60	1.22	5.3	.230	Nov. 17	7 a. m.
75	Opposite Wilson's Point	L.	532.0	103.54	1.44	102.10	0.50	0.7	.714		8 a. m.
76	Vista Landing	R.	536.5	101.76	1.44	100.32	1.78	4.5	.396		9 a. m.
77	Head of Stack Island	L.	539.6	100.38	1.47	98.91	1.41	3.1	.455		12 m.
78	Lake Providence	R.	543.0	99.10	1.46	97.64	1.27	3.4	.374		12 m.
79	Shipland Landing	L.	544.7	97.69	1.48	96.21	1.43	1.7	.841		2 p. m.
80	Bass Bend Landing										*
81	Hay's Landing (opposite)	R.	553.2	94.02	1.70	92.32	3.89	8.5	.458	Nov. 18	6 a. m.
82	Cottonwood Landing	L.	556.7	93.26	1.74	91.52	0.80	3.5	.229		9 a. m.
83	Wilson's Landing	R.	559.7	91.71	1.77	89.94	1.58	3.0	.527		10 a. m.
84	Edgewood Landing	R.	563.7	90.63	1.81	88.82	1.12	4.0	.280		12 a. m.
85	Near Foster's Landing	R.	567.0	88.20	1.83	86.37	2.45	3.3	.742		2 p. m.
86	Chotard's Landing	L.	570.4	86.22	1.86	84.36	2.01	3.4	.591		3 p. m.
87	Henderson's Landing	R.	573.5	85.35	1.89	83.46	0.90	3.1	.290		5 p. m.
88	Omega Landing	R.	578.1	84.14	2.08	82.06	1.40	4.6	.304	Nov. 19	7 a. m.
89	Below Omega	R.	578.8	83.72	2.12	81.60	0.46	0.7	.657		10 a. m.
90	Above Cabin Teele	R.	583.0	81.76	2.13	79.63	1.97	4.2	.469		10 a. m.
91	Halpins Landing	L.	585.7	80.47	2.24	78.23	1.40	2.7	.518		4 p. m.
92	Foot of Paw Paw Island	R.	589.9	78.79	2.54	76.25	1.08	4.2	.471	Nov. 20	7 a. m.
93	Young's Point	R.	594.0	78.03	2.60	75.43	0.82	4.1	.200		9 a. m.
94	King's Point	L.	596.6	77.53	2.68	74.85	0.58	2.6	.223		12 m.
95	Vicksburg or Kleinston	L.	599.2	77.89	3.62	74.27	0.58	2.6	.223	Nov. 23	2 p. m.
96	Delta Landing	R.	601.9	77.70	4.01	73.69	0.58	2.7	.215	Nov. 25	4 p. m.
97	Warrenton	L.	606.7	75.55	4.03	71.52	2.17	4.8	.452	Nov. 26	8 a. m.
98	Diamond Point	L.	611.1	74.14	3.98	70.18	1.34	4.4	0.305	Nov. 26	10 a. m.
99	Moore's Landing	R.	614.2	73.16	3.92	69.24	0.94	3.1	0.303		12 a. m.
100	New Town Landing	L.	618.5	71.79	3.84	67.95	1.29	4.3	.300		2 p. m.
101	Point Pleasant	R.	622.2	71.18	3.82	67.36	0.59	3.7	.159	Nov. 27	7 a. m.
102	Brook's Landing	L.	626.0	70.24	3.75	66.49	0.87	3.8	.229		9 a. m.
103	Wilson's Point	R.	631.2	69.64	3.00	65.98	0.51	5.2	.098		11 a. m.
104	Coffee's Point	R.	633.8	68.02	3.61	64.41	1.57	2.6	.604		1 p. m.
105	Near Whitehall Landing	L.	636.6	67.75	3.58	64.17	0.24	2.8	.086		2 p. m.
106	Above Saint Joseph	L.	641.0	66.43	3.51	62.92	1.25	4.4	.284		4 p. m.
107	Saint Joseph, La	R.	647.7	64.25	3.51	60.74	2.18	6.7	.325	Nov. 28	7 a. m.
108	Rodney	L.	651.1	64.04	3.57	60.47	0.27	3.4	.079		9 a. m.
109	Beeler's Landing	R.	655.2	63.39	3.65	59.74	0.73	4.1	.178		11 a. m.
110	Kemp's Landing	R.	659.8	60.53	3.74	56.79	2.95	4.6	.641		1 p. m.
111	Below Waterproof	R.	664.6	58.30	3.81	54.49	2.30	4.8	.479		3 p. m.
112	Cypress Grove	L.	668.9	57.29	3.89	53.40	1.09	4.3	.254		4 p. m.
113	Cole's Creek Landing	L.	672.0	56.76	4.02	52.74	0.66	3.1	.213	Nov. 29	6 a. m.
114	Above L'Argent	R.	676.0	55.27	4.10	51.17	1.57	4.0	.392		8 a. m.
115	L'Argent Landing	R.	679.3	55.21	4.16	51.05	0.12	3.3	.036		9 a. m.
116	Gibson's Landing	R.	683.4	53.98	4.24	49.74	1.31	4.1	.320		11 a. m.
117	Opposite Good Hope	L.	690.4	52.60	4.38	48.22	1.52	7.0	.217		1 p. m.
118	Stacy Plantation	R.	696.6	51.55	4.50	47.05	1.17	6.2	.189		4 p. m.
119	Natchez	L.	699.2	51.60	4.95	46.65	0.40	2.6	.154	Dec. 1	7 p. m.

* Reference bench-mark not connected with.

Tables of high and low water elevations and slopes, Mississippi River—**Continued.**

LOW-WATER SLOPE OF 1883.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day	Time of observation. Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
1	Cairo, Ill	...		298.69	—3.15	295.54	.....	..	......	Oct. 11	12 m.
2	Head of Island No. 1	L.	6.8	.. ..	.....	...	...	5.8	....	......	1 p. m.
3	△Beckwith	R.	8.8	......	...	.. ..	.....	3.0	.....	....	2 p. m.
4	Head of Puntney Bend	L.	10.3					1.5			2 p. m.
5	Foot of Puntney Bend	R.	14.1	......		...	...	3.8	......	....	3 p. m.
6	△Cannon	R.	18.0	295.21	3.32	291.89	3.05	3.9	0.203	......	4 p. m.
7	△Iron Bank	L.	20.1	297.10	5.35	291.75	0.14	2.1	.067	Oct. 23	2 p. m.
8	Columbus	L.	21.2	295.05	3.32	291.73	0.02	1.1	.018	Oct. 11	12 m.
9	△Wiggins	L.	27.3	291.79	3.36	288.43	3.30	6.1	.541	Oct. 12	7 a. m.
10	Below Farris Landing	R.	29.8	290.99	3.33	287.66	0.77	2.5	.308	......	8 a. m.
11	Thomas McMahan's	R.	32.6	289.84	3.30	286.54	1.12	2.8	.400	....	8 a. m.
12	Near Salmon's Landing	L.	34.6	289.36	3.30	286.06	0.48	2.0	.240	....	9 a. m.
13	French's Point	L.	39.7	288.64	3.25	285.39	0.67	5.1	.131	....	10 a. m.
14	Saint James's Bayou	R.	44.5	287.06	3.21	283.85	1.54	4.8	.321	....	11 a. m.
15	One mile below Lavalle's Landing	R.	48.2	...	....		....	3.7	......	....	
16	△Mitcham	L.	49.9	286.29	3.17	283.12	0.73	1.7	.185	....	1 p. m.
17	Stewart's Landing	L.	59.5	284.04	3.08	280.96	2.16	9.6	.225	....	2 p. m.
18	△Bryant's Point	R.	62.9	282.04	3.05	278.99	1.97	3.4	.579	....	3 p. m.
19	Howard's	L.	66.1	281.06	3.03	278.03	0.96	3.2	.300	....	4 p. m.
20	Morrison's Landing	R.	68.9	280.74	2.98	277.76	0.27	2.8	.096	....	12 m.
21	Below Morrison's Landing	R.	69.2	280.60	2.99	277.61	0.15	0.3	.500	....	4 p. m.
22	Marr's Landing	L.	77.3	276.24	3.02	273.22	4.39	8.1	.542	Oct. 13	7 a. m.
23	Below Point Pleasant	R.	80.3	273.25	3.01	270.24	2.98	3.0	.993	....	7 a. m.
24	Lazelle's Landing	R.	82.4	... ..	....	...	....	2.1	......	....	8 a. m.
25	Above Tiptonville	L.	84.3	.. ..	.....	..	.....	1.9	......	Oct. 13	9 a. m.
26	Opposite Tiptonville	R.	85.3	...	..	...	...	1.0	......	....	9 a. m.
27	Riley's Landing	L.	87.7	267.82	3.00	264.82	5.42	2.4	.792	....	11 a. m.
28	Below Stewart's Landing	R.	89.7	266.71	3.00	263.71	1.11	2.0	.555	....	12 m.
29	Foot of Little Cypress Bend	R.	93.3	...	2.98	....	....	3.6	......	....	1 p. m.
30	Bass Landing	[illegible]	95.1	265.49	2.97	262.52	1.19	1.8	.220	....	1 p. m.
31	Hathaway's (above)	L.	101.7	365.02	2.93	202.09	0.43	6.6	.065	....	3 p. m.
32	Below Mott's Landing	R.	104.2	261.22	2.93	*258.29	3.80	2.5	1.520	....	3 p. m.
33	Bell's Point	R.	112.0	260.31	2.89	257.42	0.87	7.8	.112	....	4 p. m.
34	Above Linwood Field	L.	114.2	258.36	2.91	255.45	1.97	2.2	.895	Oct. 14	6 a. m.
35	Mitchell's Point	L.	121.9	259.53	2.89	256.64	.....	7.7	.....	....	8 a. m.
36	Cottonwood Point	R.	123.1	254.52	2.90	251.62	3.83	1.2	430	....	12 m.
37	Helm's	R.	123.6	254.20	2.88	251.32	0.30	0.5	.600	....	9 a. m.
38	Hickman's Landing	R.	131.3	255.02	2.76	252.26	.....	7.7	.....	....	10 a. m.
39	Above Rucker's Point	L.	138.2	248.81	2.64	246.17	5.15	6.9	.853	....	11 a. m.
40	Buckner's Landing	R.	139.8	249.21	2.61	246.60	....	1.6	.....	....	12 m.
41	Above T. H. of Island No. 25	R.	142.9	247.61	2.57	245.04	1.18	3.1	.240	....	12 m.
42	Two miles above Forked Deer Island	L.	145.4	247.31	2.52	244.79	0.25	2.5	.100	....	1 p. m.
43	One mile below head of Forked Deer Island	L.	148.0	246.56	2.48	244.08	0.71	2.6	.273	....	2 p. m.
44	O'Donnell's Landing	R.	149.3	....	.....	.. ..	......	1.3			
45	Ashport, Tenn	L.	153.3	......	......	.. ....	.....	4.0			
46	Gold Dust Landing	L.	156.2	... ..	......	.. ....	......	2.9			
47	Fletcher's Landing	R.	158.0	.. ..	....	.. .	.....	1.8			
48	T. H. of Osceola Bar	R.	163.2	... ..	....	.. ..	.....	5.2			
49	Driver's Landing	R.	166.0	... ..	......	.... ..	......	2.8			
50	△Yankee Bar	L.	165.9	... ..	......	.... ..	......	—0.1			
51	Below Tanza's Landing	R.	167.7	.. ..	....	....	......	1.8			
52	Fort Pillow	L.	171.9	.	....	.... .	......	4.2			
53	Fulton, Tenn	L.	175.4	235.25	2.02	233.23	10.85	3.5	.396	Oct. 16	12 m.
54	Dixie Landing	R.	178.5	233.35	2.02	231.33	1.90	3.1	.613	....	6 a. m.
55	Hatchee River	L.	180.0	231.67	2.02	229.65	1.68	1.5	1.120	....	7 a. m.
56	Pierce's	R.	182.1	229.91	2.03	227.88	1.77	2.1	.843	....	7 a. m.
57	Half mile below Randolph	L.	183.4	229.78	2.04	227.74	0.14	1.3	.108	Oct. 15	5 p. m.
58	Richardson's Landing	L.	185.3	229.78	2.05	227.73	0.01	1.9	.005	....	5 p. m.
59	Above Pecan Point	R.	195.1	228.70	2.06	221.64	6.09	9.8	.621	....	3 p. m.
60	Below Andrew's Landing	L.	198.5	224.72	2.07	222.65	. .	3.4	......	....	1 p. m.
61	Below Thomas' Landing	L.	202.3	220.39	2.07	218.32	3.83	3.8	.461	....	12 m.
62	Corona Landing	R.	203.8	220.35	2.07	218.28	0.04	1.5	.027	....	12 m.
63	Brandywine Island	L.	206.5	218.86	2.07	216.79	1.49	2.7	.552	....	11 a. m.

* Data considered doubtful.

Tables of high and low water elevations and slopes, Mississippi River—**Continued.**

LOW-WATER SLOPE OF 1883—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation.	
										Day.	Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
64	Scudder Landing........	R.	207.8	216.91	—2.07	214.84	1.95	1.3	1.500	....	10 a. m.
65	Randolph Point..........	L.	210.9	216.66	2.06	214.60	0.24	3.1	.077	....	5 p. m.
66	Mitchell's Landing.......	L.	212.9	215.13	2.12	213.01	1.59	2.0	*.795	Oct. 17	3 p. m.
67	Below Bradley's Landing	R.	215.2	216.18	2.00	214.18	......	2.3	......	Oct. 16	11 a. m.
68	Holly Bush Landing,....	R.	219.7	212.62	2.00	210.62	2.39	4.5	.851	....	12 m.
69	Ash Slough...............	L.	221.8	211.25	2.00	209.25	1.37	2.1	.652	....	1 p. m.
70	Above Old Hen Island..	L.	224.1	210.34	2.00	208.34	0.91	2.3	.396	....	1 p. m.
71	Upper end Chicken Island	R.	225.8	......	......	......	......	1.7	......	....	1 p. m.
72	Memphis, Tenn.........	L.	230.3	208.16	2.07	206.09	2.25	4.5	.363	Oct. 17	6 a. m.
73	Fort Pickering...........	L.	232.1	202.54	2.11	200.43	......	1.8	......	Oct. 17	7 a. m.
74	Wreck of Gen. Beauregard..................	R.	233.2	......	......	......	......	1.1	......	....	8 a. m.
75	Four Mile Bayou.......	R.	235.6	207.09	2.18	204.91	1.18	2.4	0.223	....	8 a. m.
76	Jones' Landing..........	R.	238.9	203.27	2.26	201.01	3.90	3.3	1.182	....	9 a. m.
77	Above Reeves Landing..	R.	242.6	201.26	2.33	198.93	2.08	3.7	.562	....	10 a. m.
78	Coahoma Field	L.	244.1	......	......	......	......	1.5	......	....	12 m.
79	Scanlan's Landing	R.	247.7	......	......	......	......	3.6	......	....	1 p. m.
80	Cat Island................	R.	253.0	196.20	2.58	193.62	5.31	5.3	.511	....	2 p. m.
81	Norfolk Landing........	L.	254.3	194.47	2.60	191.87	1.75	1.3	1.346	....	2 p. m.
82	Star Landing............	L.	258.2	199.03	2.70	196.33	......	3.9	......	....	3 p. m.
83	Polk's Landing.........	L.	264.3	192.65	2.81	189.84	2.03	6.1	.203	....	5 p. m.
84	Excelsior Landing	R.	266.5	192.38	2.94	189.44	0.40	2.2	.182	Oct. 18	7 a. m.
85	Near Commerce	L.	269.8	189.86	3.00	186.86	2.58	3.3	.782	....	8 a. m.
86	Campbell's Landing....	R.	272.5	187.80	3.04	184.76	2.10	2.7	.778	....	8 a. m.
87	Mhoon's Landing	L.	275.8	187.00	3.12	183.88	0.88	3.3	.267	....	12 m.
88	Bordeaux Landing	L.	278.5	185.35	3.06	182.29	1.59	2.7	.589	....	11 a. m.
89	Head Bordeaux Chute..	L.	279.5	183.46	3.03	180.43	1.86	1.0	1.860	....	11 a. m.
90	Walnut Bend Landing ..	R.	282.6	183.26	2.97	180.29	0.14	3.1	.045	....	12 m.
91	Hardin's Point	R.	285.8	181.24	2.91	178.33	1.96	3.2	.612	....	12 m.
92	O. K. Landing...........	L.	289.4	180.90	2.85	178.05	0.28	3.6	.078	....	2 p. m.
93	Harbert's Landing .	L.	292.6	178.10	2.79	175.31	2.74	3.2	.856	....	2 p. m.
94	Head St. Francis Island.	R.	296.9	174.80	2.70	172.10	3.21	4.3	.747	....	3 p. m.
95	Prairie Point............	R.	300.3	173.56	2.66	170.90	1.20	3.4	.353	....	4 p. m.
96	Trotters' Landing	L.	304.0	......	......	......	......	3.7	......	....	5 p. m.
97	Helena, Ark..............	R.	306.5	170.83	2.45	168.38	2.52	2.5	.406	Oct. 18	12 m.
98	Below William's Landing	R.	310.9	170.26	2.91	167.35	1.03	4.4	.234	Oct. 19	8 a. m.
99	Thompson's Landing....	L.	313.0	167.85	2.94	164.91	2.44	2.1	1.162	....	9 a. m.
100	Near Craig's Landing...	R.	316.2	166.57	2.96	163.61	1.30	3.2	.406	....	10 a. m.
101	Miller's Point...........	R.	324.7	......	......	......	......	8.5	......	....	11 a. m.
102	Allison's Landing.......	R.	327.7	......	......	......	......	3.0	......	....	12 m.
103	Foot of Island No. 63....	L.	332.8	161.69	3.07	158.62	4.99	5.1	.301	....	1 p. m.
104	Modoc Landing..........	R.	334.5	161.31	3.08	158.23	0.39	1.7	.229	....	1 p. m.
105	Near Robinson's Landing	L.	338.2	159.52	3.11	156.41	1.82	3.7	.492	....	2 p. m.
106	Jackson's Point	L.	341.6	159.06	3.14	155.92	0.49	3.4	.144	....	3 p. m.
107	Head of Island No. 65....	R.	343.2	158.65	3.14	155.51	0.41	1.6	.256	....	3 p. m.
108	Offut's Landing..........	R.	346.7	158.55	3.17	155.38	0.13	3.5	.037	....	4 p. m.
109	Saint Louis Landing.....	R.	349.5	157.38	3.19	154.19	1.19	2.8	.425	....	5 p. m.
110	Above Fish Lake.........	L.	350.8	......	......	......	......	1.3	......	....	6 p. m.
111	Sunflower Landing......	L.	352.7	155.99	3.38	152.61	1.58	1.9	.494	Oct. 20	7 a. m.
112	Pushmataha...............	L.	359.4	154.87	3.70	151.17	1.44	6.7	.215	....	8 a. m.
113	Knowlton's Landing.....	R.	366.6	153.35	4.03	149.32	1.85	7.2	.257	....	9 a. m.
114	Australia	L.	370.0	149.33	4.21	145.12	4.20	3.4	1.235	....	10 a. m.
115	Laconia	R.	373.7	148.19	4.40	143.79	1.33	3.7	.359	....	10 a. m.
116	Below Lulu Landing....	R.	376.8	......	......	......	......	3.1	......	....	11 a. m.
117	Maysonia Landing	L.	378.4	146.74	4.64	142.10	1.69	1.6	.860	....	12 m.
118	Frawley's Landing	L.	382.4	146.27	4.84	141.43	0.67	4.0	.168	....	12 m.
119	Head Scrub Grass Bend.	R.	385.3	......	......	......	......	2.9	......	....	1 p. m.
120	Barnett's Landing	R.	387.0	142.51	5.09	137.42	4.01	1.7	.872	....	1 p. m.
121	McGeehee's Landing....	L.	391.4	140.74	5.29	135.45	1.97	4.4	.448	Oct. 20	2 p. m.
122	Cumbyville	R.	394.4	140.94	5.45	135.49	—0.04	3.0	—.013	....	3 p. m.
123	Malone's Landing, Ark	R.	397.8	......	......	......	......	3.4	......	....	4 p. m.
124	Rosedale..................	L.	398.4	140.37	5.48	134.89	0.60	0.6	.150	....	4 p. m.
125	Glen Low Landing......	R.	401.9	......	......	......	......	3.5	......	....	5 p. m.
126	Prentiss Landing	L.	403.7	138.95	5.54	133.41	1.48	1.8	.279	....	6 p. m.
127	Below foot Island No. 75	R.	407.4	......	......	......	......	3.7	......	Oct. 21	6 a. m.
128	Caulk's Landing	R.	413.3	......	......	......	......	5.9	......	....	7 a. m.
129	Bolivar, Miss	L.	417.0	133.88	5.84	128.04	5.37	3.7	.404	....	8 a. m.
130	Near Cat-Fish Point	......	......	......	......	......	......	......	......	....	9 a. m.

* Data considered doubtful.

Tables of high and low water elevations and slopes, Mississippi River—Continued.

LOW-WATER SLOPE OF 1883—Continued.

No. of station	Locality of station	Bank	Distance from Cairo.	Observed elevation of W. S. Cairo datum	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation.	
										Day.	Hour.
			Miles.	Feet.	Feet.	Feet.	Feet.	Miles.			
131	Cat Fish Point Landing	L.	422.7	132.54	5.90	126.64	1.40	5.7	.246		9 a. m.
132	Head Cypress Bend	R.	423.7					1.0			10 a. m.
133	Above Chicot City	L.	430.9					7.2			11 a. m.
134	Mound Place	R.	435.5	127.63	6.02	121.61	5.03	4.6	.393		12 m.
135	Arkansas City	R.	438.3	126.65	6.05	120.60	1.01	2.8	.361		1 p. m.
136	Old Eunice Landing	L.	442.3					4.0			2 p. m.
137	Offut's Landing	R.	444.7	125.71	5.83	119.88	0.72	2.4	.112		3 p. m.
138	Gaines's Landing	R.	449.6	124.74	5.58	119.16	0.72	4.9	.147		3 p. m.
139	Old Point Comfort	L.	454.5					4.9			4 p. m.
140	Head Miller's Bend Landing	L.	455.5					1.0			5 p. m.
141	Woodstock Landing	L.	464.2					8.7			5 p. m.
142	Llewellyn, Ark	R.	464.3	121.65	5.13	116.52	2.64	0.1	.180	Oct. 22	6 a. m.
143	Chicot Landing	R.	473.0					8.7			7 a. m.
144	△ Carter	L.	474.2					1.2			
145	Greenville	L.	478.5	118.18	4.56	113.62	2.90	4.3	.204	Oct. 22	12 m.
146	△ Jack	L.	481.7	117.71	4.50	113.21	0.41	3.2	.128		9 a. m.
147	Craig's Landing	R.	483.5	116.61	4.52	112.09	1.12	1.8	.622		10 a. m.
148	Vaucluse Landing	R.	486.9					3.4			11 a. m.
149	Sunnyside Landing	R.	490.0					3.1			11 a. m.
150	Above Walnut Point	L.	493.9					3.9			12 m.
151	Lake Port Landing	R.	495.4	112.99	4.54	108.45	3.64	1.5	.306		1 p. m.
152	Glenora, Miss	L.	498.5	112.56	4.54	108.02	0.43	3.1	.139		1 p. m.
153	Longwood Landing	L.	501.3					2.8			2 p. m.
154	Rosebank, Ark	R.	507.0	109.82	4.54	105.28	2.74	5.7	.322		3 p. m.
155	Barnard Landing	R.	509.9	109.16	4.54	104.62	0.66	2.9	.228		4 p. m.
156	Near Leota Landing	L.	511.6					1.7			5 p. m.
157	Sterling Landing	R.	515.1					3.5			5 p. m.
158	Carolina Landing	L.	516.8	107.38	4.73	102.65	1.97	1.7	.286	Oct. 23	6 a. m.
159	Ashton Landing	R	520.5	107.16	4.74	102.42	0.23	3.7	.062		7 a. m.
160	Pilcher's Point Landing	R.	523.8	104.08	4.74	99.34		3.3			8 a. m.
161	Below Lewis Plantation	L.	526.1	106.40	4.75	101.65	0.77	2.3	.137		9 a. m.
162	Opossum Point	R.	529.2	104.44	4.74	99.70	1.95	3.1	.629		9 a. m.
163	Opposite Wilson's Point	L.	531.8	103.76	4.74	99.02	0.68	2.6	.262		10 a. m.
164	Vista Landing	R.	536.5	101.83	4.75	97.08	1.94	4.7	.413		11 a. m.
165	Below Longwood Landing	R	538.1					1.6			12 m.
166	Lake Providence	R.	542.3	98.77	4.75	94.02	3.06	4.2	.528		12 m.
167	Below Lake Providence	R.	543.0	98.41	4.80	93.61	0.41	0.7	.586		2 p. m.
168	Shipland Landing	L.	544.7	97.25	4.83	92.42	1.19	1.7	.700		3 p. m.
169	Bass Bend, La	R.	548.8					4.1		Oct. 23	3 p. m.
170	Cottonwood Landing	L.	556.7	90.94	4.96	85.98	6.44	7.9	.537		4 p. m.
171	Edgewood Landing	R.	563.8					7.1			5 p. m.
172	Pecan Grove Landing	R.	566.3					2.5		Oct. 24	6 a. m.
173	Chotard's Landing	L.	570.4	84.79	5.36	79.43	6.55	4.1	.478		7 a. m.
174	Henderson's Landing	R.	573.5	84.12	5.41	78.71	0.72	3.1	.232		8 a. m.
175	Omega Landing	R.	578.0					4.5			8 a. m.
176	Cabin Teele Landing	R.	584.3					6.3			9 a. m.
177	Below Duckport	R	589.9	76.63	5.61	71.02	7.69	5.6	.469		10 a. m.
178	Young's Point	R.	593.4					3.5			11 a. m.
179	King's Point, Miss	L.	596.6	75.28	5.72	69.56	1.46	3.2	.218		12 m.
180	Kleinston or Vicksburg	L.	599.2	74.56	5.76	68.80	0.76	2.6	.292		1 p. m.
181	Warrenton, Miss	L.	606.7	72.34	5.88	66.46	2.34	7.5	.312	Oct. 25	7 a. m.
182	Diamond Point	L.	612.1		5.69			5.4			9 a. m.
183	Moore's Landing, La	R.	614.2	69.58	5.60	63.98	2.48	2.1	.331		9 a. m.
184	Upper New Town Landing	L.	618.1		5.47			3.9			10 a. m.
185	Point Pleasant Landing	R.	622.3		5.32			4.2			11 a. m.
186	Brook's Landing	L.	626.2	66.92	5.17	61.75	2.23	3.9	.186		12 m.
187	Wilson's Point Landing	R.	631.2	66.62	5.00	61.62	0.13	5.0	.026		12 m.
188	Coffee's Point	R.	634.5		4.88			3.3			1 p. m.
189	Whitehall Landing	L.	637.2	65.23	4.79	60.44	1.18	2.7	.197		2 p. m.
190	Above Bayou Pierre	L.	641.6	63.77	4.63	59.14	1.30	4.4	.295		3 p. m.
191	Saint Joseph	R.	648.3	61.38	4.37	57.01	2.13	6.7	.318		4 p. m.
192	Rodney	L.	652.0	61.10	4.44	56.66	0.35	3.7	.095		5 p. m.
193	Beeler's Landing	R.	655.3	60.73	4.52	56.21	0.45	3.3	.136	Oct. 25	6 p. m.
194	Kemp's Landing	R.	659.7		4.82			4.4		Oct. 26	6 a. m.
195	Below Waterproof	R.	665.2		4.91			5.5			7 a. m.
196	Cypress Grove	L.	669.7	54.35	4.99	49.36	6.85	4.5	.476		8 a. m.
197	Cole's Creek Landing	L.	672.0	53.28	5.03	48.25	1.11	2.3	.483		9 a. m.

Table of high and low water elevations and slopes, Mississippi River—Continued.

HIGH-WATER MARKS OF 1883—Continued.

Locality of high-water marks.	Bank.	Distance from Cairo.	Elevation, Cairo datum.	Fall between high-water marks.	Distance between high-water marks.	Slope, foot per mile.	Date high water.		Remarks.
		Miles.	*Feet.*	*Feet.*	*Miles.*				
Woodstock Plant., La ..	R.	844.0	53.311	1.107	4.4	.250	Apr.	9	
Plaquemine, La	R.	853.5	51.960	1.351	9.5	.140	Apr.	9	U. S. gauge.
Brode's Landing, La....	R.	854.8	51.828	0.137	1.3	.105	Apr.	9	
Forlorn Hope, La	L.	858.0	51.561	0.262	3.2	.080	Apr.	9	
Bayou Goula, La	R.	866.1	50.181	1.380	8.1	.170	Apr.	9	
Cora Plant., La	R.	868.7	49.339	0.842	2.6	.320	Apr.	10	
Ashland, La	L.	878.2	48.525	0.814	9.5	.080	Apr.	9	
Donaldsonville, La	R.	885.4	47.078	1.447	7.2	.200	Apr.	9	
Colombia Landing, La...	L.	897.0	45.758	1.320	11.6	.110	Apr.	9	
College Point., La	L.	903.0	44.640	1.118	6.0	.186	Apr.	8	U. S. gauge.
Belmont Plant., La	L.	906.0	43.876	0.764	3.0	.254	Apr.	9	
Mount Airy Plant., La..	L.	915.0	43.541	0.335	9.0	.037	Apr.	10	
Prospect Plant., La......	L.	935.0	39.965	3.576	20.0	.178	Apr.	9	
Kennerville, La...... ...	L.	947.0	37.683	2.282	12.0	.190	Apr.	9	
Carrollton, La..........	L.	957.0	36.310	1.373	10.0	.137	Apr.	7	U. S. gauge.
HIGH-WATER MARKS OF 1884.									
Cairo, Ill	..	0.0	342.630	....	......	......	Feb.	22	U. S. gauge.
Belmont, Mo	R.	21.3	332.220	10.410	21.3	.488	Feb.	23	U. S. gauge.
Salmon's, Ky	L.	33.6	327.147	5.073	12.3	.412	Mar.	9	
Hickman, Ky	L.	36.0	326.306	0.841	2.4	.350	Mar.	3	
Saint James Bayou, Mo..	R.	44.5	324.020	2.286	8.5	.268	Mar.	1	
Watson's Point, Ky	L.	67.8	317.680	6.340	23.3	.272	Feb.	24	
Morrison's Mo	R.	69.0	317.540	0.140	1.2	.116	Feb.	24	U. S. gauge.
Lazelle's Landing, Mo.	R.	82.4	309.210	8.330	13.4	.621	Feb.	24	
Bass Landing, Tenn. ...	L.	95.1	302.555	6.655	12.7	.524	Feb.	24	
Hathaway's, Tenn	L.	102.9	297.240	5.315	7.8	.677	Feb.	24	
Gayoso, Mo	R.	105.7	295.650	1.600	2.8	.578	Feb.	24	
Cottonwood Point, Mo...	R.	123.3	287.960	7.690	17.6	.436	Feb.	23	
Fulton, Tenn	L.	175.4	264.282	23.678	52.1	.454	Feb.	25	U. S. gauge.
Thomas Landing, Tenn..	L.	200.9	252.630	11.652	25.5	.457	Feb.	28	
Memphis, Tenn	L.	230.3	238.120	14.510	29.4	.494	Mar.	1	U. S. gauge.
Mhoon's Landing, Miss	L.	275.0	220.360	17.760	44.7	.397	Mar.	5	U. S. gauge.
Helena, Ark	R.	306.5	208.980	11.380	31.5	.361	Mar.	6	U. S. gauge.
Friar's Point, Miss	L.	319.0	202.299	6.681	12.5	.534	Mar.	7	
Miller's Point, Miss ..	L.	324.7	199.501	2.798	5.7	.491			
Saint Louis Landing, Ark	R.	349.5	189.475	10.026	24.8	.404	Mar.	6	U. S. gauge.
Sunflower, Miss	L.	352.7	188.830	0.645	3.2	.202	Mar.	6	
Beith's Landing, Ark	R.	366.1	185.686	3.144	13.4	.234	Mar.	7	
Australia, Miss	L.	369.7	184.493	1.193	3.6	.331	Mar.	7	
Cumbyville (Mo. White River)	R.	394.4	176.470	8.023	24.7	.325	Mar.	7	U. S. gauge.
Riverton, Miss	L.	399.6	173.980	2.490	5.2	.479	Mar.	9	
Niblett's, Miss	L.	414.7	170.401	3.579	15.1	.237			
Bolivar, Miss	L.	416.8	169.693	0.708	2.1	.337	Mar.	8	
Cat Fish Point, Miss .	L.	423.2	167.589	2.104	6.4	.329	Mar.	8	
Arkansas City, Ark	R.	438.3	162.710	4.879	15.1	.323	Mar.	7	U. S. gauge.
Gaines's Landing, Ark .	R.	449.5	159.690	3.020	11.2	.270	Mar.	8	
Greenville, Miss .. .	L.	478.5	149.100	10.590	29.0	.365	Mar.	8	U. S. gauge.
Leland's, Ark . ..	R.	483.5	148.052	1.048	5.0	.208	Mar.	11	
Refuge, Miss	L.	491.1	144.771	3.281	7.6	.431	Mar.	16	
Lake Providence, La	R.	542.3	128.030	16.741	51.2	.327	Mar.	23	U. S. gauge.
Delta, La	R.	597.6	115.454	12.576	55.3	.227	Mar.	23	
Vicksburg, Miss	L.	599.3	115.040	0.414	1.7	.243	Mar.	25	U. S. gauge.
Moore's Landing, La	R.	614.8	111.604	3.436	15.5	.221	....		
Newtown, Miss	L.	618.5	108.029	3.575	3.7	.966	Mar.	25	
Point Pleasant, La	R.	622.2	107.047	0.982	3.7	.265	Mar.	30	
Hard Times, La	R.	632.1	103.059	3.988	9.9	.402	Mar.	24	
Saint Joseph, La	R.	648.3	97.650	5.409	16.2	.333	Mar.	20	U. S. gauge.
Rodney, Miss	L.	651.1	96.961	0.689	2.8	.244	Mar.	23	
L'Argent, La............	R.	679.3	91.272	5.689	28.2	.202	Mar.	23	
Natchez, Miss ...	L.	700.4	84.240	7.032	21.1	.333	Mar.	24	U. S. gauge.
Bougere's Landing, La	R.	737.9	77.672	6.568	37.5	.175	....		
Black Hawk, La ..	R.	747.2	73.801	3.871	9.3	.416	Mar.	29	
Red River Landing, La .	R.	765.3	70.960	2.841	18.1	.156	Mar.	29	U. S. gauge.

Tables of high and low water elevations and slopes, Mississippi River—Continued.

HIGH-WATER MARKS OF 1884—Continued.

Locality of high-water marks.	Banks.	Distance from Cairo.	Elevation, Cairo datum.	Fall between high-water marks.	Distance between high water marks.	Slope, feet per mile	Date high water.	Remarks.
		Miles	*Feet*	*Feet.*	*Miles.*			
ort Hickey, La	L.	810.0	61.100	9.860	44.7	.221	Mar. 29	U. S. gauge.
aton Rouge, La	L.	833.3	56.270	4.830	23.3	.207	Mar. 24	U. S. gauge.
lissouri Plantation, La	R.	839.6	55.544	0.726	6.8	115	Mar. 25	
Voodstock Plantation, La.	R.	844.6	54.224	1.320	5.0	.264	Mar. 24	
laquemine, La	R.	853.5	52.660	1.564	8.9	.176	Mar. 24	U. S. gauge.
rode's Landing, La. ...	R.	854.8	52.488	0.172	1.3	.132	Mar. 24	
ayou Goula, La	R.	866.1	50.930	1.558	11.3	.187	Mar. 24	
shland, La	L.	878.2	49.355	1.575	12.1	.130	Mar. 24	
onaldsonville, La	R.	885.4	47.327	2.028	7.2	.281	Mar. 23	
olombia Landing, La ..	L.	897.7	45.654	1.673	12.3	.136	Mar. 24	
ollege Point, La ...	L.	903.0	45.290	0.364	5.3	.069	Mar. 24	U. S. gauge.
elmont Plantation, La.	L.	906.8	44.646	0.644	3.8	.169	Mar. 1–10	
lount Airy Plantation, La	L.	915.0	43.085	1.561	8.2	.190	Mar. 24	
arrollton, La	L.	957.0	36.510	6.575	42.0	.156	Mar. 18	U. S. gauge.

LOW-WATER SLOPE OF 1880.

No. of station.	Locality of station.	Bank	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Hour.
			Miles	*Feet*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
1	Cairo, Ill			300.20		300.20			*	Oct. 6	2 p. m.
2	Three States Ferry ..	L.	2.4	299.62	+ .02	299.64	0.56	2.4	0.233	.. ..	4 p. m.
3	Island No. 1 ...	L.	6.0	298.96	.07	299.03	.61	3.6	.169	Oct. 9	7 a. m.
4	△ Beckwith	R.	8.6	298.13	07	298.20	.83	2.6	.319	Oct. 9	9 a. m.
5	△ Davidson	L.	9.1	297.65	.08	297.73	47	0.5	.940	......	9 a. m.
6	△ Island No. 2	L.	12.4	297.39	.08	297.47	26	3.3	079	....	11 a. m.
7	△ Tarr ..	R.	15.1	296.96	07	297.03	.44	2.7	.163	... ..	12 m.
8	△ Cannon	R.	18.0	296.32	.08	296.40	63	2.9	217	.. ..	2 p. m.
9	Columbus, Ky ..	L.	21.2	295.90	06	295.96	44	1.2	*.138	....	3 p. m.
0	△ Thorn ...	L.	23.0	295.09	04	295.13	83	1.8	461	....	4 p. m.
1	△ Muscavally	L.	25.2	293.90	04	293.94	1.19	2.2	.541		5 p. m.
2	△ Wiggins ..	L.	27.5	292.43	.02	292.45	1.49	2.3	.648	Oct. 10	8 a. m.
3	△ Ferris Landing ..	R.	28.9	291.78	03	291.81	.64	1.4	457	......	9 a. m.
4	△ Parker	R.	32.0	290.51	.04	290.55	1.26	3.1	406	....	10 a. m.
5	Above Salmon's ..	L.	33.7	289.90	.05	289.95	60	1.7	353	....	11 a. m.
6	△ Hickman	L.	36.2	289.50	05	289.55	40	2.5	.160	.. ..	11 a. m.
7	△ Kaiser	L.	38.7	289.39	06	289.45	.10	2.5	040	....	1 p. m.
8	△ French's Point	L.	41.6	288.55	.10	288.65	.80	2.9	276	....	3 p. m.
9	△ St. James	R.	44.5	287.72	.10	287.82	83	2.9	.286	....	3 p. m.
20	Below St. James Bayou	R.	46.8	286.81	11	286.92	.90	2.3	.391	....	4 p. m.
21	△ Mitcham	L.	50.0	286.66	.13	286.79	.13	3.2	041	....	5 p. m.
22	Above △ Lester ..	L.	53.6	285.88	.27	286.15	64	3.6	178	Oct. 11	6 a. m.
23	△ Birdsall	R.	55.6	284.85	.27	285.12	1.03	2.0	.515	....	9 a. m.
24	Below △ Tennessee ..	L.	59.5	284.52	25	284.77	.35	3.9	090	...	2 p. m.
25	△ Bryant's Point	R.	62.9	282.86	.28	283.14	1.63	3.4	0.479	Oct. 11	4 p. m.
26	Below △ Everett	L.	66.1	281.35	28	281.63	1.51	3.2	.472	......	6 p. m.
27	Morrison's Landing	R.	68.9	280.65	.25	280.90	73	2.8	*.261	... .	4 p. m.
28	Below New Madrid	R.	71.1	279.01	46	279.47	1.43	2.2	650	Oct. 12	8 a. m.
29	△ Rob Watson ..	L.	74.7	277.92	45	278.37	1.10	3.6	.306	....	8 a. m.
30	Below △ Compromise	L.	77.3	276.02	.47	276.49	1.88	2.6	.723	.... ..	9 a. m.
31	△ Point Pleasant ..	R.	80.0	274.00	.46	274.46	2.03	2.7	752	......	10 a. m.
32	Above △ Gold	R.	82.7	272.97	.48	273.45	1.01	2.7	.374	....	12 m.
33	Tiptonville....	L.	85.3	270.52	.47	270.99	2.46	2.6	.946	....	12 m.

* United States gauge.

Tables of high and low water elevations and slopes, Mississippi River—Continued.

LOW-WATER SLOPE OF 1880—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Time of observation. Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
34	Below △ Stewart	R.	90.1	268.67	+.77	269.44	1.55	4.8	.323	Oct. 12	12 m.
35	Near △ Solitude	R.	93.3	267.74	.50	268.24	1.20	3.2	.375	Oct. 12	4 p.m.
36	Below △ Bass	L.	96.8	265.60	.52	266.12	2.12	3.5	.606	....	6 p.m.
37	△ Dr Smith	L.	99.6	263.29	.78	264.07	2.05	2.8	.732	Oct. 13	10 a.m.
38	Above Gayoso	L.	102.5	264.64	.82	265.46	......	2.9	(†)	....	11 a.m.
39	Gayoso	R.	105.6	262.63	.86	263.49	.58	3.1	.097	....	2 p.m.
40	△ Warden	R.	107.2	260.59	1.16	261.75	......	1.6	...	Oct. 14	10 a.m.
41	Near △ Caruthersville	R.	110.3	261.28	1.17	262.45	1.04	3.1	‡.236	....	10 a.m.
42	△ Linwood	L.	113.8	259.16	1.24	260.40	2.05	3.5	.586	....	12 m.
43	Booth's Point	L.	117.5	257.19	1.26	258.45	1.95	3.7	.527	....	12 m.
44	△ Bell's Point	L.	120.3	254.86	1.28	256.14	2.31	2.8	.825	....	3 p.m.
45	Cottonwood Point	R.	123.1	254.47	1.36	255.83	.31	2.8	*.111	....	3 p.m.
46	Lintdale	R.	125.3	253.50	1.32	254.82	1.01	2.2	.459	....	5 p.m.
47	△ Arkansas	R.	128.9	254.64	1.30	255.94	......	3.6	(§)	....	5 p.m.
48	△ Mrs. H	R.	131.3	252.28	1.27	253.56	1.26	2.4	.210	....	6 p.m.
49	Wright's Point	R.	133.7	248.96	1.53	250.49	3.07	2.4	1.279	Oct. 15	8 a.m.
50	△ Hale's Point	L.	136.0	248.52	1.51	250.03	.46	2.3	.200	....	8 a.m.
51	Near △ Nebraska	L.	138.3	248.16	1.49	249.65	.38	2.3	.165	....	9 a.m.
52	△ Buckner	R.	140.2	247.72	1.47	249.19	.46	1.9	.242	....	9 a.m.
53	Above △ Barfield	R.	141.7	247.37	1.45	248.82	.37	1.5	.247	....	10 a.m.
54	△ K. C. B	L.	144.8	......	1.43	......	......	3.1	(‖)	....	12 m.
55	Near △ Forked Deer	L.	146.4	246.26	1.41	247.67	1.15	1.6	¶.244	....	12 m.
56	Below △ Bowen	R.	149.3	247.63	1.39	249.02	......	2.9	......	....	2 p.m.
57	△ Daniel's Point	R.	152.0	245.19	1.42	246.61	1.06	2.7	.160	....	3 p.m.
58	Ashport, Tenn	L.	153.3	244.77	1.36	246.13	.48	1.3	.369	....	3 p.m.
59	Johnson's Landing	L.	156.2	244.19	1.35	245.54	.59	2.9	.203	....	4 p.m.
60	Below △ Fletcher	R.	157.5	242.96	1.33	244.29	1.25	1.3	.961	....	4 p.m.
61	Two miles below △ Fletcher	R.	159.7	241.55	1.33	242.88	1.41	2.2	.641	....	5 p.m.
62	△ Elmot	R.	161.4	241.05	1.41	242.46	.42	1.7	.247	Oct. 16	7 a.m.
63	Plum Point	L.	164.2	238.74	1.41	240.15	2.31	2.8	.825	....	8 a.m.
64	Below Osceola	R.	165.7	238.71	1.41	240.12	.03	1.5	.020	....	9 a.m.
65	Below Bullerton T. H	R	170.5	234.76	1.41	236.17	3.95	4.8	.823	....	10 a.m.
66	Fulton	L.	175.4	234.32	1.41	235.73	.44	4.9	*.090	....	11 a.m.
67	△ Lee	L.	176.9	233.60	1.45	235.05	.68	1.5	.453	....	4 p.m.
68	Near foot of Island No. 34	R.	179.8	231.60	1.45	233.05	2.00	2.9	.690	....	4 p.m.
69	Below △ Pierce	R.	182.5	228.70	1.45	230.15	......	......	......	....	5 p.m.
	Mean		182.6	......	....	230.32	2.73	2.8	.975	....	....
70	Randolph	L.	182.7	229.05	1.45	230.50	......	......	......	....	6 p.m.
71	Richardson's Landing	L.	185.8	228.78	1.41	230.19	.13	3.2	.041	Oct. 17	8 a.m.
72	Near △ Lanier	R.	188.4	227.51	1.41	228.92	1.27	2.6	.488	....	9 a.m.
73	△ Golden Lake	R.	191.5	225.12	1.41	226.53	2.39	3.1	0.771	Oct. 17	9 a.m.
74	△ Powers	R.	193.7	223.96	1.42	225.38	1.15	2.2	.523	....	10 a.m.
75	△ Pecan Point	R.	195.8	223.36	1.41	224.77	.61	2.1	.290	....	11 a.m.
76	△ Wright	L.	198.0	222.57	1.41	223.98	.79	2.2	.359	....	12 m.
77	P. B. M. No. 53	L	201.2	221.03	1.41	222.44	1.54	3.2	.481	....	4 p.m.
78	Head of Centennial Cut-off	L.	203.3	220.82	1.38	222.20	.24	2.1	.114	....	5 p.m.
79	△ Bateman	L.	207.5	217.77	1.42	219.19	3.01	4.2	**.717	Oct. 18	9 a.m.
80	Head of Fogleman's Chute	R.	207.0	217.53	1.41	218.94	3.26	4.6	.709	....	8 a.m.
							[.60	3.6	††.182]	....	
81	△ Hearn	L.	211.1	217.08	1.42	218.50	0.44	3.3	.133	....	9 a.m.
82	△ Bradley's Landing	R.	214.7	214.24	1.42	215.66	2.84	3.6	.789	....	10 a.m.
83	△ Ferguson	R.	217.9	212.40	1.42	213.82	1.84	3.2	.575	....	11 a.m.
84	△ Walt	R.	220.3	210.29	1.41	211.70	2.12	2.4	.883	....	12 m.
85	△ Morrisey	L.	224.1	209.17	1.41	210.58	1.12	3.8	.295	....	2 p.m.
86	Below Mound City	R	226.9	208.14	1.41	209.55	1.03	2.8	.368	....	3 p.m.
87	Memphis	L.	230.3	207.96	1.41	209.37	.18	3.4	*.053	....	5 p.m.
88	3 miles below Memphis	R	235.0	207.31	1.12	208.43	.94	4.7	.200	Oct. 19	12 m.
89	Opposite Foot Vice-President's Island	R	236.7	205.90	1.15	207.05	1.38	1.7	.812	....	12 m.
90	Dismal Point	R.	239.2	203.45	1.16	204.61	2.44	2.5	.976	....	12 m.
91	Below △ Ensley	L.	241.9	201.48	1.16	202.64	1.97	2.7	.730	....	2 p.m.
92	△ Watson	L.	......		1.18	......	......	......	......	....	3 p.m.

* United States gauge.
† As to elevation of reference B. M.
‡ B. M. connected with in 1883–'84.
§ Reference B. M., a stake marking △ Arkansas.
‖ Elevation of reference B. M. undetermined.
¶ W. S. referred to a P. B. M.
** In Bateman's Bend.
†† Slope through Bateman's Bend, between stations 78 and 81.

Tables of high and low water elevations and slopes, Mississippi River—Continued.

LOW WATER SLOPE OF 1880—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Time of observation. Hour.
			Miles	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
93	Above Scanlan's	L.	246.8	198.79	+1.17	199.96	2.68	4.9	.547		4 p. m.
94	Below Scanlan's	R.	249.3	197.47	1.18	198.65	1.31	2.5	.524		5 p. m.
95	Above Pickering's	R.	251.6	197.15	1.06	198.21	.44	2.3	191	Oct. 20	8 a. m.
96	Norfolk Landing	L.	253.8	196.46	1.05	197.51	.70	2.2	.318		8 a. m.
97	Star Landing	L.	258.2	195.35	1.05	196.40	1.11	4.4	.252		9 a. m.
98	Above Bennett's	R.	261.4	194.69	1.06	195.75	.65	3.2	.203		10 a. m.
99	Bennett's Landing	L.	263.0	193.46	1.06	194.52	1.23	1.6	.769		11 a. m.
100	Excelsior Landing	R.	266.5	192.44	1.07	193.51	1.01	3.5	.289		12 m.
101	Commerce	L.	269.8	190.91	1.08	191.99	1.52	3.3	.461		1 p. m.

LOW-WATER SLOPE OF 1882.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Time of observation. Hour.
1	Commerce Landing	L.	270.0	191.16	−0.72	190.44				Nov. 1	4 p. m.
2	Campbell's Landing	R.	272.4	189.98	.78	189.20	1.24	2.4	0.517	Nov. 2	8 a. m.
3	Mhoon's Landing	L.	276.0	189.39	.80	188.59	.61	3.6	.169		11 a. m.
4	Bordeaux Landing	L.	278.5	187.55	.80	186.75	1.84	2.5	.736		2 p. m.
5	Bordeaux Chute	L.	283.0	184.83	.81	184.02	2.73	4.5	.607		4 p. m.
6	O. K. Landing	L.	290.1	180.26	.82	179.44	4.58	7.1	645	Nov. 3	9 a. m.
7	Harbert's Landing	L.	293.4	180.04	.81	179.23	.21	3.3	.064		12 m.
8	Dr. Horner's	R.	299.3		.79						4 p. m.
9	Helena Island	L.	302.2		.80					Nov. 4	6 a. m.
10	Trotter's Landing	L.	303.5	172.61	.80	171.81	7.42	10.1	.735		9 a. m.
11	Helena, Ark	R.	306.2	172.53	.79	171.74	.07	2.7	*.026		6 a. m.
12	Williams Landing	R.	311.0	171.17	.74	170.43	1.31	4.8	.273		5 p. m.
13	Delta Landing	L.	314.5	168.69	.72	167.97	2.46	3.5	.703	Nov. 5	9 a. m.
14	Craig's Landing	R.	317.0	166.94	.69	166.25	1.72	2.5	.688		12 m.
15	Archie Lucas Place	L.	320.8	166.73	65	166.08	.17	3.8	.044		2 p. m.
16	Opposite Miller's Point	R.	324.2	166.58	62	165.96	12	3.4	.035		4 p. m.
17	Allison's Landing	R.	328.1		.64					Nov. 6	8 a. m.
18	Opposite Island No. 62	L.	330.2		.61						10 a. m.
19	Modoc Landing	R.	335.0	162.55	.53	162.02	3.94	10.6	.365		12 m.
20	Robson's Landing	L.	340.0	160.59	.46	160.13	1.89	5.0	.378		3 p. m.
21	Jackson's Point	L.	342.8		.42						4 p. m.
22	Offut's or Ludlow's	R.	347.1	159.41	.37	159.04	1.09	7.1	.154	Nov. 7	8 a. m.
23	Saint Louis Landing	R.	349.4	158.34	33	158.01	1.03	2.3	.448		12 m.
24	Sunflower Landing	L.	352.5	156.55	27	156.28	1.73	3.1	558		12 m.
25	Malone's Landing	L.	356.2	155.91	.22	155.69	.59	3.7	0.159	Nov 7	2 p. m.
26	Pushmataha	L.	359.3	155.49	20	155.29	.40	3.1	.129		4 p. m.
27	Foot of Island No. 68	R.	364.1	151.86	22	151.64	3.65	4.8	.760	Nov. 8	7 a. m.
28	Beith's Landing	R.	366.3	151.74	.21	151.53	.11	2.2	.050		10 a. m.
29	Australia	L.	369.6	149.99	.20	149.79	1.74	3.3	.527		11 a. m.
30	Laconia	R.	373.4	148.87	.19	148.68	1.11	3.8	.292		1 p. m.
31	Head of Island No. 71	R.	376.2		.18						3 p. m.
32	Maysonia Landing	L.	377.8	147.23	.18	147.05	1.63	4.4	.370		4 p. m.
33	Antler's	L.	381.6	146.61	.23	146.38	.67	3.8	.176	Nov. 9	8 a. m.
34	Caswell Place	R.	386.7	142.63	.22	142.41	3.97	5.1	.779		10 a. m.
35	McGehee's Landing	L.	391.1	140.58	.21	140.37	2.04	4.4	.464		12 m.
36	Terrene	L.	394.3	140.41							4 p. m.
a	Mean		394.4	140.44	.20	140.24	13	3.3	.039		
37	Cumbyville	R.	394.4	140.47						Nov. 10	7 a. m.
38	Rosedale	L.	396.2	139.74	.20	139.54	.70	3.8	.184		10 a. m.
39	Below Napoleon	R.	403.1	138.72	.20	138.52	1.02	4.9	.208		12 m.
40	Below Prentiss	L.	404.2	138.59	.20	138.39	.13	1.1	.118		1 p. m.
41	Below Ozark Island	R.	409.6		.20			5.4			3 p. m.
42	Caulk's Landing	R.	413.0	136.53	.20	136.33	2.06	8.8	.234		5 p. m.
43	Bolivar	L.	417.3	132.97	.20	132.77	3.56	4.3	.828	Nov. 11	7 a. m.
44	Cat Fish Point	L.	423.2	131.23	.20	131.03	1.74	5.9	.295		9 a. m.
45	Cypress Creek	R.	426.5	130.12	20	129.92	1.11	3.3	.336		12 m.
46	Chicot City	R.	431.8	129.50	21	129.29	63	5.3	.119		1 p. m.
47	Mound Place	L.	435.7	127.38	.22	127.16	2.13	3.9	.546		3 p. m.
48	Wilkerson's Landing	L.	436.8	126.32	23	126.09	1.07	1.1	.973		5 p. m.
49	Arkansas City	R.	439.1	126.21	.20	126.01	.08	2.3	0.035	Nov. 11	12 m.
50	Near Eunice	R.	442.5	126.10	.38	125.72	.29	3.4	.085	Nov. 12	3 p. m.
51	Offutt's Landing	L.	445.4	125.63	40	125.23	.49	2.9	.169		4 p. m.
52	Gaine's Landing	R.	450.2	124.66	.58	124.08	1.15	4.8	.240	Nov. 13	8 a. m.

* United States gauge.

Tables of high and low water elevations and slopes, Mississippi River—**Continued.**

LOW-WATER SLOPE OF 1882—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Time of observation. Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
53	Near Point Comfort	R.	458.8	123.89	—.59	123.30	.78	3.6	.217	....	10 a. m.
54	Shadyside	L.	457.4	123.00	.61	122.39	.91	3.6	.253	....	12 m.
55	Turpley Plant	L.	461.5	121.44	.63	120.81	1.58	4.1	.385	....	2 p. m.
56	Lewellyn, Ark	R.	464.7	121.28	.64	120.64	.17	3.2	.053	....	5 p. m.
57	Luna, Ark	R.	467.5	120.04	.81	119.23	1.41	2.8	.504	Nov. 14	7 a. m.
58	Opposite Point Chicot	L.	475.8	118.88	.82	118.06	1.17	8.3	.141	....	10 a. m.
59	Greenville	L.	478.5	117.86	.85	117.01	1.05	2.7	.389	....	1 p. m.
60	Jack	L.	481.7	117.43	.86	116.57	.44	3.2	.138	....	4 p. m.
61	Leland Plant	R.	483.5	116.30	.87	115.43	1.14	1.8	.633	....	5 p. m.
62	Vaucluse Landing	R.	487.1	115.77	.98	114.79	.64	3.6	.178	Nov. 15	7 a. m.
63	Sunnyside Landing	R.	490.0	114.32	.98	113.34	1.45	2.9	.500	....	8 a. m.
64	Walnut Point Landing	L.	494.8	......	.97	......	......	......	......	....	10 a. m.
65	Lake Port Landing	L.	496.1	113.22	.98	112.21	1.10	6.1	.180	....	12 m.
66	Glenora, Miss	L.	499.5	112.77	.99	111.78	.46	3.4	.135	....	2 p. m.
67	Longwood	L.	502.1	112.28	1.01	111.27	.57	[illegible]	.190	....	4 p. m.
68	Rosebank	R.	507.8	109.97	1.00	108.97	2.30	5.7	.403	....	5 p. m.
69	Near Leota Landing	L.	513.0	108.79	1.20	107.59	1.38	5.2	.265	Nov. 16	8 a. m.
70	Carolina Landing	L.	517.0	107.98	1.21	106.77	.82	4.0	.205	....	9 a. m.
71	Ashton Landing	R.	520.5	107.68	1.22	106.46	.31	3.5	.089	....	11 a. m.
72	Near Pilcher's Landing	R.	523.0	106.57	1.24	105.33	1.13	2.5	.452	....	12 m.
73	Pitman's Landing	R.	526.0	105.08	1.26	103.82	1.51	3.0	0.503	Nov. 16	3 p. m.
74	Wilson's Point	R.	531.3	104.06	1.40	102.60	1.22	5.3	.230	Nov. 17	7 a. m.
75	Opposite Wilson's Point	L.	532.0	103.54	1.44	102.10	0.50	0.7	.714	....	8 a. m.
76	Vista Landing	R.	536.5	101.76	1.44	100.32	1.78	4.5	.396	....	9 a. m.
77	Head of Stack Island	L.	539.6	100.38	1.47	98.91	1.41	3.1	.455	....	12 m.
78	Lake Providence	R.	543.0	99.10	1.46	97.64	1.27	3.4	.374	....	12 m.
79	Shipland Landing	L.	544.7	97.69	1.48	96.21	1.43	1.7	.841	....	2 p. m.
80	Bass Bend Landing										*
81	Hay's Landing (opposite)	R.	553.2	94.02	1.70	92.32	3.89	8.5	.458	Nov. 18	8 a. m.
82	Cottonwood Landing	L.	556.7	93.26	1.74	91.52	0.80	3.5	.229	....	9 a. m.
83	Wilson's Landing	R.	559.7	91.71	1.77	89.94	1.58	3.0	.527	....	10 a. m.
84	Edgewood Landing	R.	563.7	90.63	1.81	88.82	1.12	4.0	.280	....	12 a. m.
85	Near Foster's Landing	R.	567.0	88.20	1.83	86.37	2.45	3.3	.742	....	2 p. m.
86	Chotard's Landing	L.	570.4	86.22	1.86	84.36	2.01	3.4	.591	....	3 p. m.
87	Henderson's Landing	R.	573.5	85.35	1.89	83.46	0.90	3.1	.290	....	5 p. m.
88	Omega Landing	R.	578.1	84.14	2.08	82.06	1.40	4.6	.304	Nov. 19	7 a. m.
89	Below Omega	R.	578.8	83.72	2.12	81.60	0.46	0.7	.657	....	10 a. m.
90	Above Cabin Teele	R.	583.0	81.76	2.13	79.63	1.97	4.2	.469	....	10 a. m.
91	Halpins Landing	L.	585.7	80.47	2.24	78.23	1.40	2.7	.518	....	4 p. m.
92	Foot of Paw Paw Island	R.	590.0	78.79	2.54	76.25	1.98	4.2	.471	Nov. 20	7 a. m.
93	Young's Point	R.	594.0	78.03	2.60	75.43	0.82	4.1	.200	....	9 a. m.
94	King's Point	L.	596.6	77.53	2.68	74.85	0.58	2.6	.223	....	12 m.
95	Vicksburg or Kleinston	L.	599.2	77.89	3.62	74.27	0.58	2.6	.223	Nov. 23	2 p. m.
96	Delta Landing	R.	601.9	77.70	4.01	73.69	0.58	2.7	.215	Nov. 25	4 p. m.
97	Warrenton	L.	606.7	75.55	4.03	71.52	2.17	4.8	.452	Nov. 26	8 a. m.
98	Diamond Point	L.	611.1	74.14	3.96	70.18	1.34	4.4	0.305	Nov. 26	10 a. m.
99	Moore's Landing	R.	614.2	73.16	3.92	69.24	0.94	3.1	0.303	....	12 a. m.
100	New Town Landing	L.	618.5	71.79	3.84	67.95	1.29	4.3	.300	....	2 p. m.
101	Point Pleasant	R.	622.2	71.18	3.82	67.36	0.59	3.7	.159	Nov. 27	7 a. m.
102	Brook's Landing	L.	626.0	70.24	3.75	66.49	0.87	3.8	.229	....	9 a. m.
103	Wilson's Point	R.	631.2	69.64	3.66	65.98	0.51	5.2	.098	....	11 a. m.
104	Coffee's Point	R.	633.8	68.02	3.61	64.41	1.57	2.6	.604	....	1 p. m.
105	Near Whitehall Landing	L.	636.6	67.75	3.58	64.17	0.24	2.8	.086	....	2 p. m.
106	Above Saint Joseph	L.	641.0	66.43	3.51	62.92	1.25	4.4	.284	....	4 p. m.
107	Saint Joseph, La	R.	647.7	64.25	3.51	60.74	2.18	6.7	.325	Nov. 28	7 a. m.
108	Rodney	L.	651.1	64.04	3.57	60.47	0.27	3.4	.079	....	9 a. m.
109	Beeler's Landing	R.	655.2	63.39	3.65	59.74	0.73	4.1	.178	....	11 a. m.
110	Kemp's Landing	R.	659.8	60.53	3.74	56.79	2.95	4.6	.641	....	1 p. m.
111	Below Waterproof	R.	664.6	58.30	3.81	54.40	2.39	4.8	.479	....	3 p. m.
112	Cypress Grove	L.	668.9	57.29	3.89	53.40	1.00	4.3	.254	....	4 p. m.
113	Cole's Creek Landing	L.	672.0	56.76	4.02	52.74	0.66	3.1	.213	Nov. 29	8 a. m.
114	Above L'Argent	R.	676.0	55.27	4.10	51.17	1.57	4.0	.392	....	8 a. m.
115	L'Argent Landing	R.	679.3	55.21	4.16	51.05	0.12	3.3	.036	....	9 a. m.
116	Gibson's Landing	R.	683.4	53.98	4.24	49.74	1.31	4.1	.320	....	11 a. m.
117	Opposite Good Hope	L.	690.4	52.60	4.38	48.22	1.52	7.0	.217	....	1 p. m.
118	Stacy Plantation	R.	696.6	51.55	4.50	47.05	1.17	6.2	.189	....	4 p. m.
119	Natchez	L.	699.2	51.60	4.95	46.65	0.40	2.6	.154	Dec. 1	7 p. m.

* Reference bench-mark not connected with.

Tables of high and low water elevations and slopes, Mississippi River—**Continued.**

LOW-WATER SLOPE OF 1883.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
1	Cairo, Ill	...		298.69	—3.15	295.54	......	..	......	Oct. 11	12 m.
2	Head of Island No. 1	L.	5.8	..	.....	..	...	5.8	....	......	1 p. m.
3	△Beckwith	R.	8.8	......	..	..	....	3.0	....	......	2 p. m.
4	Head of Puntney Bend	L.	10.3	..	....		...	1.5	.....	......	2 p. m.
5	Foot of Puntney Bend	R.	14.1	....				3.8	.. ..	......	3 p. m.
6	△Cannon	R.	18.0	295.21	3.32	291.89	3.65	3.9	0.303	...	4 p. m.
7	△Iron Bank	L.	20.1	297.10	5.35	291.75	0.14	2.1	.067	Oct. 22	2 p. m.
8	Columbus	L.	21.2	295.05	3.32	291.73	0.02	1.1	.018	Oct. 11	12 m.
9	△Wiggins	L.	27.3	291.79	3.36	288.43	3.30	6.1	.541	Oct. 12	7 a. m.
10	Below Farris Landing	R.	29.8	290.99	3.33	287.66	0.77	2.5	.308	......	8 a. m.
11	Thomas McMahan's	R.	32.6	289.84	3.30	286.54	1.12	2.8	.400	......	8 a. m.
12	Near Salmon's Landing	L.	34.6	289.36	3.30	286.06	0.48	2.0	.240	......	9 a. m.
13	French's Point	L.	39.7	288.64	3.25	285.39	0.67	5.1	.131	......	10 a. m.
14	Saint James's Bayou	R.	44.5	287.06	3.21	283.85	1.54	4.8	.321	......	11 a. m.
15	One mile below Lavalle's Landing	R.	48.2	....	....		....	3.7	......	......	
16	△Mitcham	L.	49.9	286.29	3.17	283.12	0.73	1.7	.135	......	1 p. m.
17	Stewart's Landing	L.	59.5	284.04	3.08	280.96	2.16	9.6	.225	......	2 p. m.
18	△Bryant's Point	R.	62.9	282.04	3.05	278.99	1.97	3.4	.579	......	3 p. m.
19	Howard's	L.	66.1	281.06	3.03	278.03	0.96	3.2	.300	......	4 p. m.
20	Morrison's Landing	R.	68.9	280.74	2.98	277.76	0.27	2.8	.096	......	12 m.
21	Below Morrison's Landing	R.	69.2	280.60	2.99	277.61	0.15	0.3	.500	......	4 p. m.
22	Marr's Landing	L.	77.3	276.24	3.02	273.22	4.39	8.1	.542	Oct. 13	7 a. m.
23	Below Point Pleasant	R.	80.3	273.25	3.01	270.24	2.98	3.0	.993	......	7 a. m.
24	Lazelle's Landing	R.	82.4	......	.....	.. ..	....	2.1	......	......	8 a. m.
25	Above Tiptonville	L.	84.3	....	.....	..	.....	1.9	......	Oct. 18	9 a. m.
26	Opposite Tiptonville	R.	85.3	...	....	....	...	1.0	......	......	9 a. m.
27	Riley's Landing	L.	87.7	267.62	3.00	264.62	5.42	2.4	.732	......	11 a. m.
28	Below Stewart's Landing	R.	89.7	266.71	3.00	263.71	1.11	2.0	.555	......	12 m.
29	Foot of Little Cypress Bend	R.	93.3	..	2.96	......	......	3.6	......	......	1 p. m.
30	Bass' Landing	L.	95.1	265.49	2.97	262.52	1.19	1.8	.220	......	1 p. m.
31	Hathaway's (above)	L.	101.7	265.02	2.93	262.09	0.43	6.6	.065	......	3 p. m.
32	Below Mott's Landing	R.	104.2	261.22	2.93	*258.29	3.80	2.5	1.520	......	3 p. m.
33	Bell's Point	R.	112.0	260.31	2.89	257.42	0.87	7.8	.112	......	4 p. m.
34	Above Linwood Field	L.	114.2	258.36	2.91	255.45	1.97	2.2	.895	Oct. 14	6 a. m.
35	Mitchell's Point	L.	121.9	259.53	2.89	256.64	...	7.7	......	......	8 a. m.
36	Cottonwood Point	R.	123.1	254.52	2.90	251.62	3.83	1.2	.430	......	12 m.
37	Helm's	R.	123.6	254.20	2.88	251.32	0.30	0.5	.600	......	9 a. m.
38	Hickman's Landing	R.	131.3	255.02	2.76	252.26	.....	7.7	.....	......	10 a. m.
39	Above Rucker's Point	L.	138.2	248.81	2.64	246.17	5.15	6.9	.853	......	11 a. m.
40	Buckner's Landing	R.	139.8	249.21	2.61	246.60	.....	1.6	.....	......	12 m.
41	Above T. H. of Island No. 25	R.	142.9	247.61	2.57	245.04	1.13	3.1	.240	......	12 m.
42	Two miles above Forked Deer Island	L.	145.4	247.31	2.52	244.79	0.25	2.5	.100	......	1 p. m.
43	One mile below head of Forked Deer Island	L.	148.0	246.56	2.48	244.08	0.71	2.6	.273	......	2 p. m.
44	O'Donnell's Landing	R.	149.3	....	...	......	......	1.3			
45	Ashport Tenn	L.	153.3	......	......	......	....	4.0			
46	Gold Dust Landing	L.	156.2	......	......	......	......	2.9			
47	Fletcher's Landing	R.	158.0	......	....	......	......	1.8			
48	T. H. of Osceola Bar	R.	163.2	..	....	......	....	5.2			
49	Driver's Landing	R.	166.0	....	.....	......	......	2.8			
50	△Yankee Bar	L.	165.9	......	......	......	......	—0.1			
51	Below Tanza's Landing	R.	167.7	....	....	......	......	1.8			
52	Fort Pillow	L.	171.9		.....	....	......	4.2			
53	Fulton Tenn	L.	175.4	235.25	2.02	233.23	10.85	3.5	.396	Oct. 16	12 m.
54	Dixie Landing	R.	178.5	233.35	2.02	231.33	1.90	3.1	.613	......	8 a. m.
55	Hatchee River	L.	180.0	231.67	2.02	229.65	1.68	1.5	1.120	......	7 a. m.
56	Pierce's	R.	182.1	229.91	2.03	227.88	1.77	2.1	.843	......	7 a. m.
57	Half mile below Randolph	L.	183.4	229.78	2.04	227.74	0.14	1.3	.108	Oct. 15	5 p. m.
58	Richardson's Landing	L.	185.3	229.78	2.05	227.73	0.01	1.9	.005	......	5 p. m.
59	Above Pecan Point	R.	195.1	223.70	2.06	221.64	6.09	9.8	.621	......	3 p. m.
60	Below Andrew's Landing	L.	198.5	224.72	2.07	222.65	..	3.4	......	......	1 p. m.
61	Below Thomas' Landing	L.	202.3	220.39	2.07	218.32	1.72	3.8	.461	......	12 m.
62	Corona Landing	R.	203.8	220.35	2.07	218.28	0.04	1.5	.027	......	12 m.
63	Brandywine Island	L.	206.5	218.86	2.07	216.79	1.49	2.7	.552	......	11 a. m.

* Data considered doubtful.

Tables of high and low water elevations and slopes, Mississippi River—Continued.

LOW-WATER SLOPE OF 1883—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Time of observation. Hour.
			Miles	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
64	Scudder Landing	R.	207.8	216.91	−2.07	214.84	1.95	1.3	1.500	....	10 a. m.
65	Randolph Point	L.	210.9	216.66	2.06	214.60	0.24	3.1	.077	....	5 p. m.
66	Mitchell's Landing	L.	212.9	215.13	2.12	213.01	1.59	2.0	*.795	Oct. 17	3 p. m.
67	Below Bradley's Landing	R.	215.2	216.18	2.00	214.18	......	2.3	.....	Oct. 16	11 a. m.
68	Holly Bush Landing	R.	219.7	212.62	2.00	210.62	2.39	4.5	.351	....	12 m.
69	Ash Slough	L.	221.8	211.25	2.00	209.25	1.37	2.1	.652	....	1 p. m.
70	Above Old Hen Island	L.	224.1	210.34	2.00	208.34	0.91	2.3	.396	....	1 p. m.
71	Upper end Chicken Island	R.	225.8		....		......	1.7	.....	....	1 p. m.
72	Memphis, Tenn	L.	230.3	208.16	2.07	206.09	2.25	4.5	.500	Oct. 17	6 a. m.
73	Fort Pickering	L.	232.1	202.54	2.11	200.43	......	1.8	.....	Oct. 17	7 a. m.
74	Wreck of Gen. Beauregard	R.	233.2		......		....	1.1	.....	....	6 a. m.
75	Four Mile Bayou	R.	235.6	207.09	2.18	204.91	1.18	2.4	0.223	....	6 a. m.
76	Jones' Landing	R.	238.9	203.27	2.26	201.01	3.90	3.3	1.182	....	9 a. m.
77	Above Reeves Landing	R.	242.6	201.26	2.33	198.93	2.08	3.7	.562	....	10 a. m.
78	Cushoma Field	L.	244.1	......	....	....	......	1.5	.....	....	12 m.
79	Scanlan's Landing	R.	247.7		.....	...	......	3.6	.....	....	1 p. m.
80	Cat Island	R.	253.0	196.20	2.58	193.62	5.31	5.3	.511	....	2 p. m.
81	Norfolk Landing	L.	254.3	194.47	2.60	191.87	1.75	1.3	1.346	....	2 p. m.
82	Star Landing	L.	258.2	199.03	2.70	196.33	......	3.9	....	....	3 p. m.
83	Polk's Landing	L.	264.3	192.65	2.81	189.84	2.03	6.1	.333	....	5 p. m.
84	Excelsior Landing	R.	266.5	192.38	2.94	189.44	0.40	2.2	.182	Oct. 18	7 a. m.
85	Near Commerce	L.	269.8	189.86	3.00	186.86	2.58	3.3	.782	....	8 a. m.
86	Campbell's Landing	R.	272.5	187.80	3.04	184.76	2.10	2.7	.778	....	8 a. m.
87	Mhoon's Landing	L.	275.8	187.00	3.12	183.88	0.88	3.3	.267	....	12 m.
88	Bordeaux Landing	L.	278.5	185.35	3.06	182.29	1.59	2.7	.589	....	11 a. m.
89	Head Bordeaux Chute	L.	279.5	183.46	3.03	180.43	1.86	1.0	1.860	....	11 a. m.
90	Walnut Bend Landing	R.	282.6	183.26	2.97	180.29	0.14	3.1	.045	....	12 m.
91	Hardin's Point	R.	285.8	181.24	2.91	178.33	1.96	3.2	.612	....	12 m.
92	O. K. Landing	L.	289.4	180.90	2.85	178.05	0.28	3.6	.078	....	2 p. m.
93	Harbert's Landing	L.	292.6	178.10	2.70	175.81	2.74	3.2	.856	....	2 p. m.
94	Head St. Francis Island	R.	296.9	174.80	2.70	172.10	3.21	4.3	.747	....	3 p. m.
95	Prairie Point	R.	300.3	173.56	2.66	170.90	1.20	3.4	.353	....	4 p. m.
96	Trotters' Landing	L.	304.0		....	....	......	3.7	......	....	5 p. m.
97	Helena, Ark.	R.	306.5	170.83	2.45	168.38	2.52	2.5	.406	Oct. 18	12 m.
98	Below William's Landing	R.	310.9	170.26	2.91	167.35	1.03	4.4	.234	Oct. 19	8 a. m.
99	Thompson's Landing	L.	313.0	167.85	2.94	164.91	2.44	2.1	1.162	....	9 a. m.
100	Near Craig's Landing	R.	316.2	166.57	2.96	163.61	1.30	3.2	.406	....	10 a. m.
101	Miller's Point	R.	324.7	....	......	....	......	8.5	.....	....	11 a. m.
102	Allison's Landing	R.	327.7		......	....	......	3.0	......	....	12 m.
103	Foot of Island No. 63	L.	332.8	161.69	3.07	158.62	4.99	5.1	.301	....	1 p. m.
104	Modoc Landing	R.	334.5	161.31	3.08	158.23	0.39	1.7	.229	....	1 p. m.
105	Near Robinson's Landing	L.	338.2	159.52	3.11	156.41	1.82	3.7	.492	....	2 p. m.
106	Jackson's Point	L.	341.6	159.06	3.14	155.92	0.49	3.4	.144	....	3 p. m.
107	Head of Island No. 65	R.	343.2	158.65	3.14	155.51	0.41	1.6	.256	....	3 p. m.
108	Offut's Landing	R.	346.7	158.55	3.17	155.38	0.13	3.5	.037	....	4 p. m.
109	Saint Louis Landing	R.	349.5	157.38	3.19	154.19	1.19	2.8	.425	....	5 p. m.
110	Above Fish Lake	L.	350.8		....	....	.....	1.3	.....	....	6 p. m.
111	Sunflower Landing	L.	352.7	155.99	3.38	152.61	1.58	1.9	.494	Oct. 20	7 a. m.
112	Pushmataha	L.	359.4	154.87	3.70	151.17	1.44	6.7	.215	....	8 a. m.
113	Knowlton's Landing	R.	366.6	153.35	4.03	149.32	1.85	7.2	.257	....	9 a. m.
114	Australia	L.	370.0	149.33	4.21	145.12	4.20	3.4	1.235	....	10 a. m.
115	Laconia	R.	373.7	148.19	4.40	143.79	1.33	3.7	.359	....	10 a. m.
116	Below Lulu Landing	R.	376.8	....	....	....	......	3.1	.....	....	11 a. m.
117	Mayconia Landing	L.	378.4	146.74	4.64	142.10	1.69	1.6	.360	....	12 m.
118	Frawley's Landing	L.	382.4	146.27	4.84	141.43	0.67	4.0	.168	....	12 m.
119	Head Scrub Grass Bend	R.	385.3		....	....	......	2.9	.....	....	1 p. m.
120	Barnett's Landing	R.	387.0	142.51	5.09	137.42	4.01	1.7	.872	....	1 p. m.
121	McGehee's Landing	L.	391.4	140.74	5.29	135.45	1.97	4.4	.448	Oct. 20	2 p. m.
122	Cumbyville	R.	394.4	140.94	5.45	135.49	−0.04	3.0	−.012	....	3 p. m.
123	Malone's Landing, Ark	R.	397.8	....	......	....	......	3.4	.....	....	4 p. m.
124	Rosedale	L.	398.4	140.37	5.48	134.89	0.60	0.6	.150	....	4 p. m.
125	Glen Low Landing	R.	401.9	...	......	....	......	3.5	.....	....	5 p. m.
126	Prentiss Landing	L.	403.7	138.95	5.54	133.41	1.48	1.8	.279	....	6 p. m.
127	Below foot Island No. 75	R.	407.4	..	.....	....	.....	3.7	.....	Oct. 21	6 a. m.
128	Caulk's Landing	R.	413.3		....	....	.....	5.9	.....	....	7 a. m.
129	Bolivar, Miss	L.	417.0	133.88	5.84	128.04	5.37	3.7	.404	....	8 a. m.
130	Near Cat Fish Point	..	.....	.....	.....	.....	.....	.....	.....	....	9 a. m.

* Data considered doubtful.

Tables of high and low water elevations and slopes, Mississippi River—Continued.

LOW-WATER SLOPE OF 1883—Continued.

No. of station.	Locality of station	Bank	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of guage.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations	Slope, feet per mile.	Time of observation. Day.	Hour
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
131	Cat Fish Point Landing	L.	422.7	132.54	—5.90	126.64	1.40	5.7	.246		9 a. m.
132	Head Cypress Bend	R.	423.7					1.0			10 a. m.
133	Above Chicot City	L.	430.9					7.2			11 a. m
134	Mound Place	R.	435.5	127.63	6.02	121.61	5.03	4.6	.393		12 m.
135	Arkansas City	R.	438.3	126.65	6.05	120.60	1.01	2.8	.361		1 p. m.
136	Old Eunice Landing	L.	442.3					4.0			2 p. m.
137	Offut's Landing	R.	444.7	125.71	5.83	119.88	0.72	2.4	.112		3 p. m.
138	Gaines's Landing	R.	449.6	124.74	5.58	119.16	0.72	4.9	.147		3 p. m.
139	Old Point Comfort	L.	454.5					4.9			4 p. m.
140	Head Miller's Bend Landing	L.	455.5					1.0			5 p. m.
141	Woodstock Landing	L.	464.2					8.7			5 p. m.
142	Llewellyn, Ark	R.	464.3	121.65	5.13	116.52	2.64	0.1	.180	Oct. 22	6 a. m.
143	Chicot Landing	R.	473.0					8.7			7 a. m.
144	△ Carter	L.	474.2					1.2			
145	Greenville	L.	478.5	118.18	4.56	113.62	2.90	4.3	.204	Oct. 22	12 m.
146	△ Jack	L.	481.7	117.71	4.50	113.21	0.41	3.2	.128		9 a. m.
147	Craig's Landing	R.	483.5	116.61	4.52	112.09	1.12	1.8	.622		10 a. m.
148	Vaucluse Landing	R.	486.9					3.4			11 a. m.
149	Sunnyside Landing	R.	490.0					3.1			11 a. m.
150	Above Walnut Point	L.	493.9					3.9			12 m.
151	Lake Port Landing	R.	495.4	112.99	4.54	108.45	3.64	1.5	.306		1 p. m.
152	Glenora, Miss	L.	498.5	112.56	4.54	108.02	0.43	3.1	.139		1 p. m.
153	Longwood Landing	L.	501.3					2.8			2 p. m.
154	Rosebank, Ark	R.	507.0	109.82	4.54	105.28	2.74	5.7	.322		3 p. m.
155	Barnard Landing	R.	509.9	109.16	4.54	104.62	0.66	2.9	.228		4 p. m.
156	Near Leota Landing	L.	511.6					1.7			5 p. m.
157	Sterling Landing	R.	515.1					3.5			5 p. m.
158	Carolina Landing	L.	516.8	107.38	4.73	102.65	1.97	1.7	.286	Oct. 23	6 a. m.
159	Ashton Landing	R.	520.5	107.16	4.74	102.42	0.23	3.7	.062		7 a. m.
160	Pilcher's Point Landing	R.	523.8	104.08	4.74	99.34		3.3			8 a. m.
161	Below Lewis Plantation	L.	526.1	106.40	4.75	101.65	0.77	2.8	.137		9 a. m.
162	Opossum Point	R.	529.2	104.44	4.74	99.70	1.95	3.1	.629		9 a. m.
163	Opposite Wilson's Point	L.	531.8	103.76	4.74	99.02	0.68	2.6	.262		10 a. m.
164	Vista Landing	R.	536.5	101.83	4.75	97.08	1.94	4.7	.413		11 a. m.
165	Below Longwood Landing	R.	538.1					1.6			12 m.
166	Lake Providence	R.	542.3	98.77	4.75	94.02	3.06	4.2	.528		12 m.
167	Below Lake Providence	R.	543.0	98.41	4.80	93.61	0.41	0.7	.586		2 p. m.
168	Shipland Landing	L.	544.7	97.25	4.83	92.42	1.19	1.7	.700		3 p. m.
169	Bass Bend, La	R.	548.8					4.1		Oct. 23	3 p. m.
170	Cottonwood Landing	L.	556.7	90.94	4.96	85.98	6.44	7.9	.587		4 p. m.
171	Edgewood Landing	R.	563.8					7.1			5 p. m.
172	Pecan Grove Landing	R.	566.3					2.5		Oct. 24	6 a. m.
173	Chotard's Landing	L.	570.4	84.79	5.36	79.43	6.55	4.1	.476		7 a. m.
174	Henderson's Landing	R.	573.5	84.12	5.41	78.71	0.72	3.1	.232		8 a. m.
175	Omega Landing	R.	578.0					4.5			8 a. m.
176	Cabin Teele Landing	R.	584.3					6.3			9 a. m.
177	Below Duckport	R.	589.9	76.63	5.61	71.02	7.69	5.6	.460		10 a. m.
178	Young's Point	R.	593.4					3.5			11 a. m.
179	King's Point, Miss	L.	596.6	75.28	5.72	69.56	1.46	3.2	.218		12 m.
180	Klein'ston or Vicksburg	L.	599.2	74.56	5.76	68.80	0.76	2.6	.292		1 p. m.
181	Warrenton, Miss	L.	606.7	72.34	5.88	66.46	2.34	7.5	.312	Oct. 25	7 a. m.
182	Diamond Point	L.	612.1		5.69			5.4			9 a. m.
183	Moore's Landing, La	R.	614.2	69.58	5.60	63.98	2.48	2.1	.331		9 a. m.
184	Upper New Town Landing	L.	618.1		5.47			3.9			10 a. m.
185	Point Pleasant Landing	R.	622.3		5.32			4.2			11 a. m.
186	Brook's Landing	L.	626.2	66.92	5.17	61.75	2.23	3.9	.186		12 m.
187	Wilson's Point Landing	R.	631.2	66.62	5.00	61.62	0.13	5.0	.026		12 m.
188	Coffee's Point	R.	634.5		4.86			3.3			1 p. m.
189	Whitehall Landing	L.	637.2	65.23	4.79	60.44	1.18	2.7	.197		2 p. m.
190	Above Bayou Pierre	L.	641.6	63.77	4.63	59.14	1.30	4.4	.295		3 p. m.
191	Saint Joseph	R.	648.3	61.38	4.37	57.01	2.13	6.7	.318		4 p. m.
192	Rodney	L.	652.0	61.10	4.44	56.66	0.35	3.7	.095		5 p. m.
193	Becler's Landing	R.	655.3	60.73	4.52	56.21	0.45	3.3	.136	Oct. 25	6 p. m.
194	Kemp's Landing	R.	659.7		4.82			4.4		Oct. 26	6 a. m.
195	Below Waterproof	R.	665.2		4.91			5.5			7 a. m.
196	Cypress Grove	L.	669.7	54.35	4.99	49.36	6.85	4.5	.476		8 a. m.
197	Cole's Creek Landing	L.	672.6	53.28	5.03	48.25	1.11	2.9	.483		9 a. m.

Tables of high and low water elevations and slopes, Mississippi River—**Continued.**

LOW-WATER SLOPE OF 1883—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum.	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum.	Fall between stations.	Distance between stations.	Slope, feet per mile.	Time of observation. Day.	Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
198	Two and three-fourths miles above L'Argent Landing	R.	676.3	52.91	—5.10	47.81	0.44	4.3	.102		9 a. m.
199	L'Argent Landing	R.	679.3	51.75	5.16	46.59	1.22	3.0	.407		10 a. m.
200	Gibson's Landing	R.	683.5	50.50	5.22	45.28	1.31	4.2	.312		10 a. m.
201	Moses's Wood-yard	L.	689.3	49.18	5.32	43.86	1.42	5.8	.245		12 m.
202	Stacy Plantation	R.	696.6		5.45			7.3			12 m.
203	Natchez, upper end	L.	699.6	48.13	5.50	42.63	1.23	3.0	.119		1 p. m.
204	Natchez Gauge	L.	700.4	47.43	5.50	41.93	0.70	0.8	.875		12 m.
205	Carthage Landing	L.	703.1	47.26	5.53	41.73	0.20	2.7	.074		2 p. m.
206	Boles Point	R.	707.4	45.25	5.51	39.74	1.99	4.3	.463		3 p. m.
207	Opposite Morville Landing	L.	710.5	44.82	5.49	39.33	0.41	3.1	.132		3 p. m.
208	Apex of Saint Catherine Bend	R.	712.7		5.50			2.2			4 p. m.
209	Avalanche Landing	L.	718.3		5.46			5.6			4 p. m.
210	Green's Landing	R.	720.5	40.82	5.46	35.36	3.97	2.2	.397		5 p. m.
211	Below Ashley Plantation	R.	724.2		5.71			3.7		Oct. 27.	6 a. m.
212	Fairview Landing	R.	727.6	39.35	5.70	33.65	1.71	3.4	.241		7 a. m.
213	In Dead Man's Bend	L.	730.8	39.35	5.69	33.66	—0.01	3.2	—.003		8 a. m.
214	Allaway's Landing	L.	735.4	38.45	5.68	32.77	0.89	4.6	.193		9 a. m.
215	Bougere Landing	R.	737.9	41.18	5.67	35.51		2.5			10 a. m.
216	Above Union Point Landing	R.	741.0		5.67			3.1			11 a. m.
217	Kienstra Landing	L.	742.9	37.04	5.66	31.38	1.39	1.9	0.195	Oct. 27	12 m.
218	Black Hawk Landing	R.	747.2	36.35	5.64	30.71	0.67	4.3	.156		12 m.
219	Stump's Landing	L.	750.8		5.63			3.6			1 p. m.
220	Knox's Landing	R.	753.0	35.55	5.62	29.93	0.78	2.2	.134		2 p. m.
221	Fort Adams	L.	755.2		5.61			2.2			2 p. m.
222	Lum's Landing	R.	758.0	35.19	5.59	29.60	0.33	2.8	.066		3 p. m.
223	Point Old River and Miss.	R.	764.2		5.56			6.2			4 p. m.
224	Red River Landing	R.	765.3	33.69	5.56	28.13	1.47	1.1	.201		4 p. m.
225	Hog Point Landing	R.	767.0	33.45	5.71	27.74	0.39	1.7	.229	Oct. 28	6 a. m.
226	Bayou Tunica	L.	773.0	32.40	5.56	26.90	0.84	6.0	.140		8 a. m.
227	Greenwood Landing	L.	777.0	32.12	5.45	26.67	0.23	4.0	.058		8 a. m.
228	Brunette Light Landing	R.	779.5	31.81	5.37	26.44	0.23	2.5	.092		9 a. m.
229	Sebastopol Landing	L.	782.2		5.30			2.7			9 a. m.
230	Raccourci Landing	R.	784.8	31.10	5.22	25.88	0.56	2.6	.106		10 a. m.
231	Morganza Crevasse	R.	789.1		5.12			4.3			11 a. m.
232	Head Arrow Bend		791.9		5.04			2.8			11 a. m.
233	Mann's Landing		795.1	30.01	4.96	25.05	0.83	3.2	.081		12 m.
234	Point Coupée	R.	797.9	29.96	4.86	25.10	—0.05	2.8	—.018		12 m.
235	Bayou Sara	L.	799.5	29.39	4.83	24.56	0.54	1.6	.338		1 p. m.
236	Waterloo, La	R.	805.2	29.35	4.08	24.67	—0.11	5.7	—.019		2 p. m.
237	Hermitage Landing	R.	807.8	28.58	4.62	23.96	0.71	2.6	.273		3 p. m.
238	Port Hickey	L.	810.0	28.36	4.56	23.80	0.16	2.2	.073		3 p. m.
239	Kelson's Store	R.	813.6	28.12	4.38	23.74	0.06	3.6	.017		4 p. m.
240	Lower Springfield Landing	L.	818.9		4.14			5.3			5 p. m.
241	Grossman's Landing	R.	822.6	28.01	3.94	24.07	—0.33	3.7	—.037	Oct. 28	5 p. m.
242	Belle Valle Plantation	R.	825.5	27.62	4.09	23.59	+0.48	2.9	+.166	Oct. 29	6 a. m.
243	Scotland Landing	L.	828.5	27.14	3.87	23.27	0.32	3.0	.107		7 a. m.
244	Baton Rouge	L.	833.3	27.36	3.63	23.73	—0.46	4.8	—.096		8 a. m.
245	Arlington Plantation	L.	836.9	26.90	3.48	23.42	0.31	3.6	+.086		9 a. m.
246	Conrad's Cottage Plantation	L.	840.0	26.40	3.30	23.10	[redacted]	3.1	.103		9 a. m.
247	Saint Mary Plantation	R.	841.0		3.34			1.0			9 a. m.
248	Hollywood	L.	845.0	26.38	3.31	23.07	[redacted]	4.0	.006		10 a. m.
249	Above Plaquemine	L.	847.2	25.11	3.23	21.88		2.2			11 m.
250	Plaquemine	R.	853.5	25.78	3.67	22.01	0.16	6.3	.019		12 m.
251	Rebecca Plantation	R	856.6	21.21	2.80	18.41		3.1			1 p. m.
252	Saint Gabriel's Church	L.	861.6	25.58	2.68	22.90	0.01	5.0	.001		2 p. m.
253	Above Bayou Goula	L.	864.9	25.46	2.60	22.86	0.04	3.3	.012		3 p. m.
254	Cora Plantation	R.	868.8		2.50			3.9			3 p. m.
255	Indian Camp Plantation	L.	870.8	25.31	2.45	22.86	0.00	2.0	.000		4 p. m.
256	Southwood Plantation	L.	874.4	24.94	2.36	22.58	0.28	3.6	.078		4 p. m.
257	Ashland Landing	L.	878.2	25.06	2.28	22.78	—0.20	3.8	—.063		5 p. m.
258	New Hope Plantation	L.	881.6		2.19			3.4			5 p. m.
259	Above Donaldsonville	L.	884.4	25.10	2.21	22.89	—0.11	2.8	—.018	Oct. 30	6 a. m.
260	Riverside, La	R.	887.1	25.27	2.16	23.11	—0.22	2.7	—.081		7 a. m.
261	Houma's Estate	L.	889.7		2.10			2.6			

Tables of high and low water elevations and slopes, Mississippi River—Continued.

LOW-WATER SLOPE OF 1883—Continued.

No. of station.	Locality of station.	Bank.	Distance from Cairo.	Observed elevation of W. S. Cairo datum	Correction for change of gauge.	Corrected elevation of W. S. Cairo datum	Fall between stations.	Distance between stations.	Slope, feet, per mile.	Time of observation. Day.	Hour.
			Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Miles.*			
262	Colomb's Store	L.	896.7	24.62	−1.94	22.68	+0.43	7.0	+.045		9 a. m.
263	Rome & Dubon's Store	L.	899.9		1.87			3.2			9 a. m.
264	College Point	L.	903.0	24.49	1.81	22.68	0.00	3.1	.000		10 a. m.
265	Belle Alliance Plantation	L.	907.8		1.78			4.8		Oct. 30	12 m.
266	Mount Airy Plantation	L.	915.0	24.08	1.71	22.37	0.31	7.2	.026		1 p. m.
267	Bell's Point, La	L.	916.8		1.70			1.8			1 p. m.
268	Old Bonnet Carré Post-Office	R.	926.5	23.91	1.60	22.31	0.06	9.7	.005		2 p. m.
269	Bonnet Carré Camp	L.	927.5		1.69			1.0			2 p. m.
270	Below Gypsy Plantation	L.	929.9	23.76	1.56	22.20	0.11	2.4	.032		4 p. m.
271	Myer's Landing	R	932.0		1.54			2.1			4 p. m.
272	Fashion Landing	R	936.7		1.50			4.7			5 p. m.
273	Kennerville	L	947.0	23.22	1.39	21.83	0.37	10.3	.022	Oct. 31	6 a. m.
274	Willswith Plantation	R.	950.1		1.36			3.1			7 a. m.
275	Soniat's Plantation	L	951.1	23.67	1.35	22.32		1.0			7 a. m.
276	Carrollton	L.	957.0	22.71	1.30	21.41	0.42	5.9	.042		8 a. m.
277	Near Barrataria Canal	R.	958.5		1.28			1.5			9 a. m.
278	Gretna	R.	962.6		1.24			4.1			10 a. m.
279	New Orleans (foot Canal street)	L.	964.9		1.21			2.3			10 a. m.

APPENDIX D.

REPORT OF CAPTAIN J. H. WILLARD, CORPS OF ENGINEERS, SECRETARY OF COMMITTEE ON CONSTRUCTION.

THE MISSISSIPPI RIVER COMMISSION,
OFFICE OF THE COMMITTEE ON CONSTRUCTION,
2653 *Olive Street, Saint Louis, Mo., June* 30, 1885.

SIR: In compliance with your letter of instructions, dated June 1, 1885, I have the honor to report the work of this office from October 1, 1884, the date of my last annual report, to the close of the fiscal year, June 30, 1885.

The general service plant, comprising the Commission tow-boat Mississippi, the tow-boat Minnetonka, twenty-eight flush-deck barges, twenty-eight deck-down barges, and a few miscellaneous pieces, is now laid up in safe harbor at Twin Hollows, about 15 miles below Saint Louis.

The tow-boats are in very good order, and could be put in service at a day's notice in an emergency, the Minnetonka having been recently overhauled and strengthened and equipped with iron cylinder timbers. The barges are in fair condition, and could all be put in service at short notice, with the exception of three, which require general repairs. All wooden hulls have been washed out, cleaned, and salted, to preserve the timbers. The bottom planking appears to be sound and the seams well filled, so that no repairs or calking will be necessary until operations are resumed, when it will be advisable to dock most, if not all, of the barges and give them a general overhauling, as they will then have been in the water about four years. The tow-boats may have to be docked for cleaning and painting, but no calking or repairs to hulls should be required. The boilers of the Mississippi should be reset before she is put on active work as a tow-boat, as the port boiler has given out repeatedly, either from defective circulation or inequality in the spaces between the shells and side-walls. An extra beam and stanchions are needed under the after end of boilers on the Minnetonka. The supports now rest on the deck between beams, causing considerable vibration, especially when running light.

The repairs to the Minnetonka were somewhat more extensive than was expected owing to developed weakness in the hull and faulty distribution of weights in placing the engines, but her behavior during the short period of service since the repairs were completed satisfied me that the money was judiciously invested. She now has the

name of being the best tow-boat of her size on the river, and with proper attention should be good for at least eight years' service. I had her lines and dimensions taken while on the docks, from which drawings and a model are now being made for use in building the large steel tow-boat, when authority for its construction is renewed.

The thirty small barges borrowed from the Missouri River Improvement were returned in March and April in fair order. About $2,500 have been spent for docking and repairing them since October 1, 1884, which, with the sum given in my last report, makes the amount expended for their repair while in general service, about $3,700. During that time they carried and delivered 23,961 cubic yards of stone and were used temporarily for brush and timber on the reaches, so that the cost of repairs was equivalent to about 15 cents the cubic yard for transportation or to about 45 cents a day for charter. The actual cost of charter for equal capacity, computed from ruling rates, would have been about $4 a day for each barge.

These figures are interesting as bearing upon the question whether it is more advantageous to the Government to own or to charter. For works prosecuted on a large scale and requiring a term of years, such as the improvement of the Mississippi, there can be no doubtful choice. I therefore renew my request for increase of the general service plant, with the addition of small barges for service to the Ohio quarries, especially in low water, and a few medium-sized barges for delivering coal to districts The estimates are based on recent contracts for barges and for the hull of a steel snag-boat, and from informal offers for boilers, engines, and upper works, and are ample, unless there should be a very considerable advance in prices on the revival of business.

In regard to the construction of barges, the experience of the past season with the Missouri River gunwale barges leads me to recommend that form instead of the modeled barge. If planked fore and aft, with easy rakes, they will tow and handle in block almost as easily as model barges, and the saving in construction is such that they can be built of equal capacity for the same money in the proportion of about 3 to 2. Detailed drawings and specifications for both sizes of barge are now ready, and drawings, specifications, and models for the tow-boats are well in hand, those for the hull of the small tow-boat being finished.

I also renew the suggestions contained in my last report in regard to the purchase and delivery of Illinois coal. Eleven well-built coal barges of, say, 9,000 bushels capacity, would be enough to supply the three districts below Cairo and the general service, and would pay for themselves in one year on the basis of prices and amounts of last year's purchases. If it still be thought better to buy Pittsburgh coal for the districts, it should be contracted for delivery at the works, or, if received at Cairo, should be delivered by the general service at the first opportunity. It would certainly conduce to economy of the service to have three or four coal barges of moderate capacity to accompany the tow-boats on long trips. Prices last year ranged from 11¼ cents at Cairo to 16⅜ cents at Arkansas City for Pittsburgh lump on board, while Illinois lump from the Big Muddy was delivered on the boats at Grand Tower for 6¼ cents the bushel. Making due allowance for the acknowledged inferiority of Illinois coal, the saving would probably not fall much below 25 per cent.

I have but little to suggest in regard to the new tow-boats. In general they should have ample boilers, long-stroke engines with variable cut-off, and, probably, open heaters with circulating coils, and the conventional "doctor" for feeding boilers. Vertical heaters are preferable for the saving in fuel and in the time required for cleaning boilers, but they are objectionable on account of their great size and weight, the difficulty in locating them so that they may be cleaned and drained readily, and lastly from the high pressure required.

The heater put on the Minnetonka, in place of the old one which was worn out, takes the feed-water through a coil into the pan, where it stands at less than 4 inches depth, and delivers it to the boilers at about 206° F. As this arrangement works well, I think it will be best to equip the new boats in the same way, unless it be thought advisable to use independent vertical heaters for each cylinder. For the large boat, four steel boilers, with double steam-drums, and engines 20 inches diameter by 10½ feet stroke, are recommended, and for the small boat three steel boilers, and engines 15 inches diameter by 7 feet stroke. All steam and hot-water pipes and cylinders to be jacketed, and the latter finished with wood lagging.

The upper works should be strong and simple, without ornamentation, and arranged so as to give comfortable accommodations for the crew. For both boats I recommend large hollow shafts of Whitworth compressed steel. As they can be imported free of duty, the cost would probably not exceed that of American iron or steel solid shafts of greater weight for equal strength. The amount asked for the construction of these boats remains the same, but the proportions are changed to $55,000 for the large and $35,000 for the small boat, the estimates being based on the price per pound for the hull of the steel snag-boat now building at Pittsburgh, and from informal offers for machinery, boilers, and upper works from builders in this city.

Should the plant remain laid up till July, 1886, about $16,800 will be required for docking and general repairs to barges, and for docking the tow-boats, for cleaning, resetting boilers, and minor repairs. I also make an estimate for general and extraordinary repairs for the year, and estimates for running expenses and fuel, on the supposition that active operations will be resumed and that the plant will be suitably increased.

As the conditions were favorable for work during the autumn, heavy demands were made for stone and supplies, especially for the first district. Unfortunately, the low stage of the Ohio prevented getting out much stone from the quarries about Golconda, and scarcity of labor or lack of enterprise retarded the output from the Mississippi quarries. Later in the season stone was taken from quarries as far north as Grafton, all available barges being chartered to expedite the delivery. Contrary to general expectation, severe cold weather set in early, and by December 17 navigation was suspended, leaving the work about half done and the floating property in danger. Considerable stone was lost and a number of barges were sunk, but through the exertions of employés the barges were saved with little damage. The extreme cold prevailed so long that after one or two attempts to deliver tows to the first district the work was given over, and when Congress adjourned without making further appropriations, the floating property was collected and laid up.

All of the stone was purchased in open market at prices ranging from 50 to 60 cents the cubic yard, except for that from the Grafton quarries, which was delivered at Saint Louis for 75 cents, including charter and towing between the quarries and the city. During November and December about 31,000 cubic yards were delivered to the districts, 2,500 yards were lost on the way or thrown overboard to save barges, and about 3,000 yards were afloat at Cairo on the suspension of operations; the latter, not having been paid for, was sold, in order to clear the barges and settle with the parties who furnished it. There remained about 16,000 yards at the quarries ready for loading, most of which was at Chester and Grand Tower. Fair settlements were made with the quarrymen for stone thrown overboard and lost, and the Government freed from liability on account of stone quarried under former agreements. The movement of stone since October 1, 1884, is given in tabular form.

There were three serious losses of property during the season. The chartered barge Morning Star, loaded with about 330 tons of galvanized steel wire, 10 tons of spike, and 87 pieces of dimension timber, for the first district, was sunk in Saladin Channel, October 6. The barge was a total loss, which fell upon owners and insurance company. The cargo was valued at $25,651.71, most of which was saved during the month; the actual value of the property recovered being $24,556, at a cost of $1,727 for wrecking tools and labor.

Chartered barge Missouri No. 4, loaded with stone for the first district, was sunk on a snag near Belmont in November, the loss of the barge falling on the owner.

In the same month general-service barge No. 167, loaded with stone, struck a snag below Cario and sank. An attempt was made to raise it, which proved unsuccessful. Missouri River barge No. 57 was sunk on the way to Plum Point with a load of stone, but was raised and repaired.

November 3 the starboard cylinder-timber of the Minnetonka was found to be broken under the cylinder. The Jack Frost was chartered to take her tow to Lake Providence and fetch the empty barges chartered for the work at New Orleans. The timber was repaired so as to fit her for service temporarily, and has since been replaced by an iron beam.

The expenditures for general service have been apportioned among the districts according to the work done, as computed from the mileage, those for outfit and repairs being divided equally among the first, second, and third. Three hundred and eighty-two pieces have been moved down-stream and 567 pieces up-stream since October 1, the excess of up-stream movement being due to consolidation of the second district plant with that of the first, and towing the general service and Commission fleets to Twin Hollows. The service was equivalent to towing one piece 133,533 miles. The statement of work and apportionment of cost are given in tabular form.

The amount available for general service October 1, 1884, was $291,635.56, of which $97,825.88 have been expended and charged to districts; $58,000 transferred to Lake Providence, and $8,000 to Vicksburg Harbor, Delta Point. The balance available July 1, 1885, is $127,809.68, of which $12,000 will be required for care of property and contingencies to June 30, 1886, and a portion at least should be reserved for putting the plant in running order on resuming operations.

I present herewith directory of the Commission, with its officers and districts under improvement, estimates for general service 1886–'87, statement of plant, statement of general-service mileage, movement of stone, detailed statement of expenditures by the general service, detailed financial statement of all expenditures from October 1, 1884, to June 30, 1885, and a general statement of appropriations and expenditures from March 3, 1881, to June 30, 1885.

THE MISSISSIPPI RIVER COMMISSION.

Col. and Bvt. Maj. Gen. QUINCY A. GILLMORE, Corps of Engineers, president, 33 West Houston street, New York.
Lieut. Col. and Bvt. Brig. Gen. CYRUS B. COMSTOCK, Corps of Engineers, 33 West Houston street, New York.
Maj. CHARLES R. SUTER, Corps of Engineers, 1415 Washington avenue, Saint Louis.
HENRY MITCHELL, civil engineer, United States Coast and Geodetic Survey, 9 Pemberton square, Boston.
B. M. HARROD, civil engineer, Cotton Exchange Building, New Orleans.
S. W. FERGUSON, civil engineer, Greenville, Miss.
Hon. ROBERT S. TAYLOR, post-office box 1648, Fort Wayne Ind.
Capt. THOMAS TURTLE, Corps of Engineers, secretary, 2828 Washington avenue, Saint Louis.

THE COMMITTEE ON CONSTRUCTION.

Messrs. GILLMORE, COMSTOCK, SUTER, and HARROD.
Capt. JOSEPH H. WILLARD, Corps of Engineers, secretary and assistant, 2653 Olive street, Saint Louis.

OFFICERS OF CORPS OF ENGINEERS IN CHARGE OF DISTRICTS.

Des Moines Rapids to Illinois River, 165 miles.

Capt. ERNEST H. RUFFNER, Quincy, Ill.

Illinois River to Ohio River, 245 miles.

Maj. OSWALD H. ERNST, custom-house, Saint Louis.

First district, Ohio River to foot of Island No. 40 (Plum Point Reach), 220 miles.

Capt. SMITH S. LEACH, custom-house, Cairo, Ill., and Elmot, Ark.

Second district, foot of Island No. 40 to White River (Memphis Reach), 180 miles.

Capt. SMITH S. LEACH, 280 Front street, Memphis, Tenn.

Third district, White River to Warrenton, Miss. (Lake Providence Reach), 220 miles.

Capt. CLINTON B. SEARS, 106 Madison street, Memphis, Tenn., and Wilson's Point, La.

Fourth district, Warrenton to Head of Passes, 484 miles.

Maj. AMOS STICKNEY, 3 South Rampart street, New Orleans.

General service estimates, 1886–'87.

One large steel tow-boat	$55,000		
One small steel tow-boat	35,000		
		$90,000	
11 coal-barges		22,000	
12 small gunwale barges		24,000	
32 large gunwale barges		96,000	
			$232,000
General repairs to plant on resuming operations		16,800	
General and extraordinary repairs during year		9,000	
			25,800
			257,800
Running expenses of tow-boats:			
Mississippi, eight months, at $3,400		27,200	
Minnetonka, ten months, at $3,600		36,000	
New large tow-boat, three months, at $3,600		10,800	
New small tow-boat, three months, at $2,400		7,200	
		81,200	
500,000 bushsels Illinois coal, on board, at 8 cents		40,000	
			121,200
Office salaries, rent, and contingencies		12,000	
Administration and inspection		5,000	
Fleet and care of property		4,000	
			21,000
			$400,000

Approximate value of plant belonging to the United States and used upon the improvement of the Mississippi River, general service.

Class of property.	Approximate value June 30, 1885.
1 steamer, Mississippi	$60,000
1 steamer, Minnetonka	40,000
1 pump-boat	1,000
1 store-boat	500
2 sounding-boats	40
1 yaul	40
28 barges (flush deck)	33,000
28 barges (low deck)	50,400
Office furniture	400
Total value	185,380

Statement of mileage of general-service tow-boats from October 1, 1884, to June 30, 1885.

Tow-boat.	For first district.	For second district.	For third district.	For general service.	Total.
Mississippi	23,274	12,006	7,621	8,781	51,682
Minnetonka	19,590	26,496	4,207	5,964	56,256
Pearl	15,296	1,101	526	825	17,748
Jack Frost			7,847		7,847
	58,160	39,603	20,201	15,560	133,633

Movement of stone from October 1, 1884 to June 30, 1885.

At fleet and in tow, October 1, 1884	cubic yards	8,178		
From Mississippi quarries	do	32,001		
From Ohio quarries	do	13,069		
				53,248
Delivered to first district	do	23,026		
Delivered to second district	do	13,395		
Delivered to third district	do	5,015		
Delivered to fourth district	do	4,392		
			45,828	
Lost at quarries, fleet, and in tow	do	4,165		
Sold	do	3,255		
			7,420	
				53,248

Expenditures by Capt. J. H. Willard, secretary committee on construction, Mississippi River Commission, on account appropriation for Improving Mississippi River, no limit, from allotment for general service, from October 1, 1884, to June 30, 1885.

Plant and outfit	$3,719 09
Repairs to plant	19,276 71
Care of public property	6,351 14
Administration and inspection	2,132 30
Office expenses, rent, and repairs	7,877 45
Barge charter	1,334 00
Running expenses steamer Mississippi	18,537 99
Running expenses steamer Minnetonka	14,708 01
Running expenses steamer Pearl	11,840 91
Running expenses steamer Jack Frost	5,620 63
Stone lost by sinking	2,103 60
Raising sunken barges	3,123 30
Towage	795 35
United States Marine Hospital Service	403 40
Total	$97,825 88

The above expenditures apportioned as follows:

To first district	$44,303 85
To second district	30,503 67
To third district	21,657 75
To fourth district	1,360 61
Total	$97,825 88

FINANCIAL STATEMENT.

October 1, 1884, to June 30, 1885.

General service.

Available October 1, 1884		$291,635 56
Transferred to Lake Providence	$58,000 00	
Transferred to Delta Point	8,000 00	
Expended account Plum Point Reach	44,303 85	
Expended account Memphis Reach	30,503 67	
Expended account Lake Providence Reach	21,657 75	
Expended account New Orleans Harbor	1,360 61	
		163,825 88
Balance in Treasury	70,000 00	
Balance in hand	57,809 68	
		127,809 68

Des Moines Rapids to Illinois River.

Available October 1, 1884		181,748 65
Transferred to snag-boat service		5,000 00
Balance		176,748 65
Received from sale of fuel		43 89
Total		176,792 54
Expended		90,034 49
Balance in Treasury	$65,000 00	
Balance in hand	21,758 05	
		86,758 05

Illinois River to Ohio River and protection of the easterly bank of the Mississippi near Cairo.

Available October 1, 1884		$459,109 58
Received from sale of fuel		70 43
Total		459,180 01
Expended, Illinois River to Ohio River	$323,888 90	
Expended, Cairo	22,431 08	
		346,319 98
Balance in Treasury	75,000 00	
Balance in hand	37,860 03	
		112,860 03

New Madrid Reach.

Available October 1, 1884	2,141 09
Expended	3 00
Balance in hand	2,138 09

Plum Point Reach.

Available October 1, 1884		320,243 88
Drawn from Treasury for general service		44,303 85
Total		364,547 73
Expended		348,042 62
Balance in Treasury	$11,520 00	
Balance in hand	4,985 11	
		16,505 11

Saint Francis Front—First District.

Available October 1, 1884	$126 89
Expended	0 00
Balance in hand	126 89

Memphis Reach.

Available October 1, 1884	55,626 09
Drawn from Treasury for general service	30,503 67
Received from sale of fuel	11 25
Total	86,141 01
Expended	86,071 77
Balance in hand	69 24

Memphis Harbor.

Available October 1, 1884	129,211 87
Received from sale of fuel	22 50
Total	129,234 37
Expended	127,792 84
Balance in hand	1,441 53

Saint Francis Front—Second District.

Allotment expended before October 1, 1884.

Survey of Helena Reach.

Allotment expended before October 1, 1884.

Lake Providence Reach.

Available October 1, 1884	$263,492 67
Drawn from Treasury for general service	21,657 75
Transferred from general service	58,000 00
Transferred from Tensas Front	7,700 00
Transferred from Yazoo Front	2,000 00
Transferred from Choctaw Bend	1,320 14
Received from sale of fuel	31 50
Total	354,202 06
Expended	332,131 61
Balance in hand	22,070 45

Vicksburg Harbor (dredging).

Allotment expended before October 1, 1884.

Vicksburg Harbor (Delta Point).

Available October 1, 1884	$10,720 69
Transferred from unallotted reserve	4,000 00
Transferred from general service	8,000 00
Total	22,720 69
Expended	19,037 81
Balance in hand	3,682 88

Survey of unleveed fronts—Third District.

Available October 1, 1884		51
Expended		51
Balance in hand		00

Choctaw Bend survey.

Available October 1, 1884		1,320 14
Transferred to Lake Providence		1,320 14
Balance in hand		0 00

New Orleans Harbor.

Available October 1, 1884	$45,403 07	
Reverted to Treasury	123 42	
		45,279 65
Transferred from Red River		900 00
Drawn from Treasury for general service		1,360 61
Total		47,540 26
Expended		46,943 69
Balance in hand		596 57

Mouth of Red River.

Available October 1, 1884		22,499 42
Transferred to New Orleans Harbor		900 00
Balance		21,599 42
Expended		17,783 34
Balance in hand		3,816 08

Natchez and Vidalia.

Available October 1, 1884		2,672 92
Expended		1,046 97
Balance in hand		1,625 95

Observations at Carrollton.

Allotment expended before October 1, 1884.

Survey of unleveed fronts—Fourth District.

Available October 1, 1884	$97 88
Expended	97 88
Balance	0 00

Survey of Cubitt's Gap.

Available October 1, 1884	162 86
Expended	0 00
Balance in hand	162 86

Levees—Second District.

Yazoo Front.—Allotment expended before October 1, 1884.

Long Lake:

Available October 1, 1884	14,984 45
Expended	14,984 45
Balance	0 00

Levees—Third District.

Tensas Front:		
Available October 1, 1884		57,186 47
Transferred to Lake Providence		7,700 00
Balance		49,486 47
Expended		49,454 21
Balance in hand		32 26
Yazoo Front:		
Available October 1, 1884		23,594 25
Transferred to Lake Providence		2,000 00
Balance		21,594 25
Expended		21,419 70
Balance in hand		174 55
Opossum Fork:		
Available October 1, 1884		25,000 00
Expended		25,000 00
Balance		0 00

Levees—Fourth District.

Atchafalaya Front:		
Available October 1, 1884		19,091 60
Transferred to Tensas Front		3,000 00
Balance		16,091 60
Expended		6,595 53
Balance in hand		9,496 07
Tensas Front:		
Available October 1, 1884		92,973 37
Transferred from Atchafalaya Front		3,000 00
Transferred from unallotted reserve		8,710 00
Total		104,683 37
Expended		104,071 61
Balance in hand		611 76
Total available October 1, 1884 (levees)		232,830 14
Transferred from unallotted reserve		8,710 00
Total		241,540 14
Transferred to Lake Providence		9,700 00
Balance		231,840 14
Expended		221,525 50
Balance in hand		10,314 64
Total available October 1, 1884, for Improving Mississippi River		2,031,753 91
Reverted to Treasury	$123 42	
Transferred to snag-boat service	5,000 00	
		5,123 42
Balance		2,026,630 49
Received from sale of fuel		179 57
Total		2,026,810 06
Expended		1,636,832 01
Balance available July 1, 1885, to meet liabilities and to carry on work under the Mississippi River Commission		389,978 05

Statement of funds available for Improving Mississippi River, from March 3, 1881, to June 30, 1885.

Act of March 3, 1881		$1,000,000 00
Act of August 2, 1882		4,123,000 00
Act of January 19, 1884		1,000,000 00
Act of July 5, 1884, less $5,000 transferred to snag-boat service		2,065,000 00
Total specific appropriations		8,188,000 00
Balances from former appropriations applied to works below Cairo, under act of August 2, 1882, less $123.42 reverted to Treasury	$272,504 96	
Same for works above Cairo, under act of July 5, 1884	22,632 53	
Total balances		295,137 49
Received from sale of fuel and loss of property		411 07
Total available		8,483,548 56
Expended to June 30, 1885		8,093,570 51
Balance available July 1, 1885		389,978 05

Detailed statement of funds applied to Improving Mississippi River, under the Mississippi River Commission, from March 3, 1881, to June 30, 1885.

Districts.	From appropriations.	From balances.	From sales.	Total available.	Expended.	Balances in Treasury.	Balances in hand.	Total balances.
Des Moines Rapids to Illinois River	$195,000 00	$12,663 58	$43 69	$207,707 27	$120,949 22	$65,000 00	$21,758 05	$86,758 05
Illinois River to Ohio River	470,000 00	9,969 15	70 43	480,039 58	389,339 56	75,000 00	15,700 02	90,700 02
Protection near Cairo	50,000 00			50,000 00	27,839 99		22,160 01	22,160 01
	520,000 00	9,969 15	70 43	530,039 58	417,179 55	75,000 00	37,860 03	112,860 03
Survey Saint Francis Front	5,000 00			5,000 00	4,873 11		126 89	126 89
New Madrid Reach	212,500 00		2 83	212,502 83	210,364 74		2,138 09	2,138 09
Plum Point Reach	2,395,424 53		99 70	2,395,524 23	2,379,019 12	11,520 00	4,985 11	16,505 11
Totals First District	2,612,924 53		102 53	2,613,027 06	2,594,256 97	11,520 00	7,250 09	18,770 09
Survey Saint Francis Front	4,000 00			4,000 00	4,000 00			
Survey Helena Reach	8,000 00			8,000 00	8,000 00			
Levees—Long Lake	15,000 00			15,000 00	15,000 00			
Levees—Yazoo Front	80,950 00			80,950 00	80,950 00			
Memphis Harbor	200,000 00		22 50	200,022 50	198,580 97		1,441 53	1,441 53
Memphis Reach	477,121 81		20 47	477,142 28	477,073 04		69 24	69 24
Totals Second District	785,071 81		42 97	785,114 78	783,604 01		1,510 77	1,510 77
Survey unleveed fronts	1,000 00			1,000 00	1,000 00			
Survey Choctaw Reach	2,679 66			2,679 66	2,679 66			
Levees—Opossum Fork	25,000 00			25,000 00	25,000 00			
Levees—Yazoo Front	365,050 00			365,050 00	364,875 45		174 55	174 55
Levees—Tensas Front	411,140 00			411,140 00	411,107 74		32 26	32 26
Vicksburg Harbor—dredging	61,812 12			61,812 12	61,812 12			
Vicksburg Harbor—Delta Point	92,486 46	25,770 13		118,256 59	115,573 71		2,682 88	2,682 88
Lake Providence Reach	2,262,210 18		140 00	2,262,350 18	2,240,285 73		22,070 45	22,070 45
Totals Third District	3,222,384 62	25,770 13	140 00	3,248,294 75	3,222,334 61		25,960 14	25,960 14
Survey Cubitt's Gap	300 00			300 00	137 14		162 86	162 86
Survey unleveed fronts	1,000 00			1,000 00	1,000 00			
Observations at Carrollton	3,000 00			3,000 00	3,000 00			
Bonnet Carré Crevasse	15,000 00			15,000 00	15,000 00			
Natchez and Vidalia harbors		8,252 04		8,252 04	6,626 09		1,625 95	1,625 95

Detailed statement of funds applied to Improving Mississippi River, under the Mississippi River Commission, &c.—Continued.

Districts.	From appropriations.	From balances.	From sales.	Total available.	Expended.	Balances in Treasury.	Balances in hand.	Total balances.
New Orleans Harbor	$2,260 61	$147,670 39	....	$149,931 00	$149,334 43	....	$596 57	$596 57
Mouth of Red River	11,390 00	90,812 40	....	102,202 40	98,386 32	....	3,816 08	3,816 08
Levees—Tensas Front	548,870 00	....	....	548,870 00	548,258 24	....	611 76	611 76
Levees—Atchafalaya Front	143,000 00	....	....	143,000 00	133,503 93	....	9,496 07	9,496 07
Totals Fourth District	724,820 61	246,734 83	....	971,555 44	955,246 15	....	16,309 29	16,309 29
General service	127,798 43	....	$11 25	127,809 68	....	$70,000 00	57,809 68	127,809 68
Grand totals	8,188,000 00	295,137 49	411 07	8,483,548 56	8,093,570 51	221,520 00	168,458 05	389,978 05

Respectfully submitted.

J. H. WILLARD,
Captain of Engineers, Secretary Committee on Construction.

APPENDIX E.

REPORT OF CAPTAIN E. H. RUFFNER, CORPS OF ENGINEERS, UPON THE IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE DES MOINES RAPIDS AND THE MOUTH OF THE ILLINOIS RIVER.

UNITED STATES ENGINEER OFFICE,
Quincy, Ill., June 17, 1885.

SIR: I have the honor to render the following report of operations on the improvement of the Mississippi River from the Des Moines Rapids to the mouth of the Illinois River, for the interval October 1, 1884, to June 30, 1885:

UNITED STATES DREDGE-PLANT.

This plant, consisting of the tow-boats Nos. 3 and 4, dredge No. 2, launch, and barges, the whole under charge of Assistant Engineer W. A. Thompson, operated between Canton and Quincy.

The fence-dam previously built between Island 420 and the Illinois shore, opposite La Grange, had been damaged by the passage through it of a raft, and was repaired.

This dam, at the close of the year 1884, consumed materials at prices and in amounts as follows:

[Fence-dam, Island 420, 1,000 feet long; shore protections, 400 feet.]

Materials, &c.	Quantity.	Cost.	Average cost.	Remarks.
Gravel .... cubic yards..	12,133	$1,337 57	$0.102	Dredged and deposited on dam.
Do .... do ...	5,444	1,254 30	.23	Dredged and shoveled on dam.
Stone and brush .... do....	2,645	2,176 68	.823	
Bulkhead .... feet...	835	} 454 07	....	
Frame .... do....	1,388		....	
Piles .... do....	2,268		....	
Total		5,222 62	....	

This dam was injured by the ice in the spring of 1885, and was repaired by day labor and the use of Government plant, the stone being procured by public notice and sealed proposals at the following rates (all other materials are also included):

Materials, &c.	Cubic yards.	Average cost.	Amount.
Stone	2,044.90	$0.70	$1,431 43
Brush	*540	....	....
Do	†260.79	....	....
Subsistence	....	....	219 31
Labor	....	....	618 34
Launch	....	....	212 67
Sundries	....	....	29 13
Total	....	....	2,510 88

*On hand. †Cut.

Which, added to prior sum, gives a total of $7,632.50, or an average cost per running foot of $5.45.

A short closing-dam, 325 feet long, 400 feet shore-protection, between islands 419 and 418, was built in October. Stone and brush, 2,816.39 cubic yards, cost $2,824.61, or an average cost per running foot of $3.90.

A wing-dam, known as 4.66, begun in September, 1884, and located just above the head of Island 419, is 1,200 feet long, with a T head 175 feet long, and has 200 feet shore-protection. The dam is built on gravel foundation, and was raised to a height of 4 feet above low-water mark; completed November 6, 1884.

Materials, &c.	Cubic yards.	Total cost.	Average per yard.
			Cents.
Stone and brush	7,293	$6,974 49	95.6
Gravel	16,095	1,834 83	11.4
Bulkhead	....	293 16	....
Total cost	....	$9,102 48	....

Average cost per running foot, $5.15.

To facilitate the scouring action of the two dams, spurs from Island 418, the dredge cut a channel, in November, through Wyaconda Bar, finishing November 25; length 1,500 feet, width 50 feet, depth 8 feet; cost as follows: 7,813 cubic yards; cost, $851.57: average, 10.89 cents. November 7 to 29 was employed in building shore-protection, 2,100 feet long, on west side small island at mouth of Quincy Bay.

Stone and brush, 4,133 cubic yards; cost, $3,642.33; average, 88.12 cents; average cost per running foot, $1.73.

This fleet laid up November 29. The dredge did not work continuously, partly owing to high water, partly to breakages. The dredge has been put in thorough repair during the winter, but has not been in operation this spring.

Some repairs have been necessary to the brush fence-dam from Island 427 to the Missouri shore, in October:

Stone .... cubic yards ..	492
Brush .... do	75
Piles	20

Besides a small break repaired in one day in April. Total cost of these repairs, $1,049.66, not easily divided into items.

Dredging in Quincy Bay has continued during the fall and spring under the contract with H. S. Brown, reported last year. A channel 2,900 feet long and 100 feet wide at the bottom has been cut through the bar at the mouth of Whipple's Creek; and a cut has been made to the mouth of the creek, so as to divert therein its waters, in order to preserve the channel across the bar. Special areas in the bay have been dredged where necessary, and a large amount of the bar removed directly, without reference to channels; 68,204.7 cubic yards in all have been dredged, at a total cost of $9,548.65, including retained payments. This dredging will be continued until the amount of the contract, $12,500, is exhausted. Mr. George Waters is acting as inspector.

BROKAU ISLAND DAM.

The contract made September 24 with Patterson Brothers, as already reported, for the construction of a closing-dam between Island 458, "Brokau" Island, and the Illinois shore, was carried to completion. It was about three-fourths finished in 1884, and completed in 1885. This dam rests upon a gravel foundation, and above that is of the usual brush and stone construction. Its cost and material account is as follows:

Materials.	Cubic yards.	Total cost.	Average cost.
Gravel	19,760	$4,940 00	$0 25
Piling		60 00	
Stone	11,882.22	16,041 00	1 35
Brush	8,445.25	5,489 41	65
Total		26,530 41	

Total length of dam 1,200 feet and shore protection 1,750 feet. Average cost of the whole per running foot, $8.93. During construction this dam suffered a serious break in the spring of 1885. The expenses of inspection have not been included above. Messrs. J. C. McElhorne, A. W. Buel, and C. M. Bennett, have acted as inspectors at different times on this work. Final work done and contract completed in May.

UNITED STATES TOW-BOAT NO. 5, AND PLANT.

This plant, the steamer Coal Bluff, was in charge of Overseer C. M. Bennett, and on October 1, 1884, was engaged in building dam between Bolter's Island No. 515, and its tow-head. This dam 375 feet long with 400 feet shore protection, besides 850 feet shore protection on the tow-head itself, was finished in October.

Repairs were also made at the same time to the dam running from Island 514 to Island 515, and also that from Island 514, Dardenne Island, to Islands 513 and 512, known as Dardenne Dam.

These works consumed materials as follows:

Materials.	Cubic yards.	Total cost.	Average cost.
Stone	5,476	$7,664	$1.016
Brush	2,063		

A break in the Hannibal Dam, 250 feet in length, and 8 feet in depth, from the shore out, was repaired, together with other smaller breaks further out.

Material account.

Materials.	Cubic yards.	Total cost.	Average cost.
Stone	2,418	$3,359	$1 10
Brush	653		

A bad break in Denmark Dam, from Island 450 to the Illinois shore, was repaired in November. This break extended from the Illinois shore to within 200 feet of Denmark Island, and was brought to a height of 7 feet above low water, except on a part of the line. Advent of cold weather forced a suspension before completion.

Material account.

Materials.	Cubic yards.	Total cost.	Average cost.
Stone	4,515	$6,089 05	$1 09
Brush	1,081		

These items do not include the expenses of the steamer which when apportioned to the whole, and the entire amount of material handled during the season is considered, gives an average of $1.056 per cubic yard for putting in place 16,201 cubic yards of material.

The fleet went into winter-quarters in Quincy Bay November 27. The Coal Bluff needing extensive repairs, advertisement was made in December for proposals to do the principal carpenter work. No bids were received, however, and the work was done by hired labor during the winter and spring.

Bids were opened, after due advertisement, on February 19, for new boilers for the Coal Bluff, and the contract awarded to the Iowa Iron Works Company, Dubuque, Iowa, for $2,095. The boilers are in place, and the boat ready for use. Total cost of repairs, $5,371.61.

During the season of 1884 work was impeded by lack of barges, and one was bought, and bids asked for five new ones, for the future. Bids were opened December 10, and the contract awarded to J. R. Morgan & Son, Clinton, Iowa. These barges have been built and delivered at a cost of $7,500, besides the expenses of inspection. Two new quarter-boats, under contract in the fall, were received, at a cost of $830. The entire plant has been put in good order, and is ready for use.

SURVEYS.

Surveys were made during the fall by Inspector J. C. McElherne:

I. At the foot, and for a mile up Hamburg Bay, over bars which now impede navigation.

II. At Cap au Gris, where numerous islands divide the river into channels, none of them deep or permanent.

III. From the head of Bolter's Island to the foot of Island 522.

These surveys were intended to base new work upon. At Whitney's Bar, above Hannibal Bridge, surveys made early as 1884, by Assistant Engineer Chaffee, have been platted. This is with reference to future work.

An edition of the maps of the survey of 1878, of this part of the river, was prepared for photolithographing and forwarded for reproduction.

These maps are for general use and to accompany reports.

In March, Overseer Bennett and Inspector McElherne made a survey of the bar at the mouth of Whipple Creek, in Quincy Bay, in order to base the further work under the dredging contract there. This has been platted. These gentlemen afterwards made surveys in front of Quincy and at Brokau Island, to determine the effect of recent constructions at these places. No decided changes are reported, and the plats show a gradual but not marked improvement. In April, Inspector McElherne made a survey of 3 miles to cover Wyaconda and Howard's bars above La Grange to ascertain the effect of last year's work; not platted yet, and in June Messrs. Bennett and McElherne, surveyed for 9 miles above Island 413, to base future work upon; and made one of 3 miles opposite Cincinnati Landing and Gilbert's Island, to determine amount of work needed there. These last surveys are not platted.

Financial statement in detail to cover period from July 1, 1884, to June 30, 1885, is given, and the estimate of the value of plant.

An allotment of $5,000 was made by the Secretary of War, towards meeting the expenses of the snag-boat, operating the Upper Mississippi River. No operations are proposed until extreme low water, when urgent demands will be met if possible, and temporary channels made where required.

Very respectfully, your obedient servant,

E. H. RUFFNER,
Captain of Engineers.

Col. QUINCY A. GILLMORE,
Corps of Engineers, President Mississippi River Commission.

FINANCIAL STATEMENT.

Appropriation July 5, 1884		$200,000 00
Received from Captain Ruffner, sale of fuel		43 89
Total		$200,043 89
Expended by Major Mackenzie	$9,513 61	
Rxpended by Captain Ruffner, to October 1, 1884	8,737 74	
Expended by Captain Ruffner, October 1, 1884, to June 30, 1885:		
Care and maintenance of plant	4,436 14	
Dams between Canton and La Grange	11,910 19	
Dredging in Quincy Bay	8,593 79	
Louisiana Brokan Island Dam	25,933 81	
Operations Coal Bluff and barges	3,137 97	
Office expenses	5,471 52	
Plant	9,882 48	
Quincy shore protection	4,313 28	
Repairs to Brush Fence Dam	1,049 66	
Repairs to Hannibal Dam	2,192 07	
Repairs of Denmark Dam	6,125 48	
Repairs to steamer Coal Bluff, including new boilers	5,371 61	
Survey account	3,155 59	
Gauge account	27 00	
Total expenditures	109,851 94	
Balance on contract, H. S. Brown	3,906 21	
Allotted for continuing snagging operations, Upper Mississippi River	5,000 00	
		118,758 15
Balance available June 30, 1885		$81,285 74

Approximate value of plant belonging to the United States and used upon the improvement of Mississippi River from Des Moines Rapids to mouth of Illinois River—Illinois and Missouri.

Class of property.	Approximate value, June 30, 1885.
Steamer Coal Bluff	$15,000 00
Launch Irene	1,500 00
6 model barges, at $2,700	16,200 00
3 model barges (Nos. 48, 49, and 51), at $1,000	3,000 00
1 old barge (No. 53)	300 00
1 coal flat	1,000 00
5 new flats, at $1,500	7,500 00
1 new flat	1,100 00
1 pile-driver and tender	1,600 00
1 dredge	22,500 00
6 dump-boats, at $900	5,400 00
1 quarter-boat	1,000 00
2 quarter-boats, at $400	800 00
2 quarter-boats, worthless	....
8 skiffs, at $15	120 00
Tools and appliances	800 00
Surveying instruments	850 00
Office furniture	200 00
Total	$78,870 00

APPENDIX F.

REPORT OF MAJOR O. H. ERNST, CORPS OF ENGINEERS, UPON THE IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., June 18, 1885.

COLONEL: In compliance with the instructions contained in your letter of the 1st instant, to "prepare a brief report of operations in the district under your [my] charge from the date at which the last annual report leaves them, to June 30, 1885," I have the honor to submit the following:

My last annual report brought the history of the works down to October 1, 1884. At that date operations were in progress at Horsetail, Twin Hollows, Pulltight, Jim Smith's, and Cairo, and had been begun at Alton, but at that locality were temporarily suspended on account of high water. In addition to continuing these works, some work has been done at Arsenal Island and Cahokia Chute, and Chesley Island. All of these except Alton and Cairo form part of the continuous series of works just below Saint Louis.

ALTON.

The work of filling up the depressions in the dike opposite and above the city, and of raising the general level of its crest, was resumed November 1, and continued to December 3, when it was suspended. The quantity of material placed was 5,253 cubic yards riprap. The dike was completed to its full height of 14 feet above standard low water over a distance of 4,000 feet, measured from its shore-end. The remaining portion of the dike, 800 feet in length, is left at a lower level. The good results at the Alton landing previously reported have been maintained. No further work is required here for the present.

ARSENAL ISLAND AND CAHOKIA CHUTE.

The revetment at the head of Arsenal Island was completed this spring by being carried up to the top of the bank for a distance of 675 feet on the west side and 355 feet on the east side, both measured from the up-stream point of the island. A temporary protection, consisting of a mattress 40 feet wide, was also placed on the east side, extending from the end of the permanent protection to Hurdle No. 2, across Cahokia Chute. Some small repairs were made in Hurdles Nos. 1 and 2, across Cahokia Chute. Heavy additional deposits have been secured in the chute. The least depth of channel found in this vicinity since my last report was 12 feet.

HORSETAIL.

In continuing the protection of the new bank on the west side the revetment was carried up to a height of from 16 to 21 feet above standard low water for a length of 2,140 feet and to a height of 11 feet for a length of 620 feet. The total length of this revetment is 3,910 feet over which distance all erosion has been stopped.

Upon the Illinois side Hurdles Nos. 27½ and 29½, which were nearly finished at the date of my last report, were completed and No. 31, which had just been begun, was built to its full length of 2,675 feet. A new hurdle, No. 32, was laid out about 1,000 feet below No. 31, and was built to its full length of 2,775 feet. Nos. 31 and 32 were completed except that for a length of 800 feet at the outer end of No. 31 and 300 feet at the outer end of No. 32 the wattling was not carried to the tops of the piles but was left at a level 8 feet above standard low water. This was done in accordance with my regular practice not to bring too heavy a strain upon the hurdles at first in deep water. The wattling will be continued to full height after the hurdles shall have been reinforced by deposits. Some extensive repairs were found necessary in the Carroll's Island hurdle, which were made. Heavy additional deposits have been secured on both sides of the river. The least depth of channel found in the Horsetail Reach since my last report was 9 feet.

TWIN HOLLOWS, WEST SIDE.

The repairs in the primary hurdle and in secondary Nos. 4 and 5 were completed The construction of an additional hurdle, to be called No. 6, had been contemplated, but the idea was abandoned for the present, when Congress adjourned without renewing the appropriations. Large additional deposits have been secured here. The least depth of channel found in this vicinity since my last report was 8½ feet.

TWIN HOLLOWS, EAST SIDE.

The extension down-stream of the revetment at this place was continued. The mattress, 120 feet wide, to be placed below low-water mark, which at the date of my last report had reached a length of 990 feet, was extended 1,835 feet, making its total length 2,825 feet. Being thus connected with the head of the Pulltight work, it was cut loose from the ways and sunk. Riprap was deposited upon the bank above low-water mark, raising the revetment to higher levels at various parts of the old and new work, where the bank had been graded to a proper slope by the action of the river.

From Station 22 to Station 47, and from 76 to 81, it was raised to a height 16 feet above standard low water, and from Station 87 + 50 to Station 93 + 75 to a height 10 feet above the same plane. The total length of this revetment is 11,400 feet. Some portions of it, particularly at the down-stream end, will be raised to higher levels in the future as the upper bank takes a proper slope. All of it stands intact.

PULLTIGHT.

The construction of Hurdle No. 4, which was progressing at the date of my last report, was completed. A new hurdle, called No. 3, was laid out about 1,300 feet below No. 2, and built out to a distance of 550 feet from shore, where it connected with a high bar. Some repairs were made in Nos. 1 and 2 and in the primary hurdle. Large additional deposits have been secured among the hurdles.

CHESLEY ISLAND.

The revetment placed in former years at Chesley Island stands intact. It was thought desirable, however, to raise the level of the portion of it near the head of the island to the full height of the bank. This was done for a distance of 590 feet on the east side and 410 feet on the west side. The hurdle in the chute west of the island remains in bad condition. The reduction of force made necessary by the failure of the river and harbor bill at the last session of Congress has rendered it impracticable to repair it this spring, as was contemplated. It is expected that that can be done during the coming year with funds now available.

JIM SMITH'S.

The primary hurdle was repaired and reinforced for a length of 1,600 feet from shore, where it terminated, and the thirteen secondary hurdles contemplated in the project were practically completed. No. 1 is 1,050 feet long; No. 2, 1,640 feet; No. 2½, 2,010 feet; No. 3, 1,800 feet; No. 3½, 1,525 feet; No. 4. 1,300 feet; No. 4½, 1,170 feet; No. 5, 1,070 feet; No. 5½, 1,115 feet; No. 6, 890 feet; No. 6½, 780 feet; No. 7, 890 feet; No. 7½, 1,050 feet. Nos. 3½ and 5½ were slightly damaged by ice during the winter, and were repaired; Nos. 1, 2, 2½, 3, 3½, 4, 4½, 5, and 5½ were completed to their full length. Nos. 6, 6½, 7, and 7½ extend from shore to a high bar near the proposed new shore-line. A heavy rise in the river brought the work to a close about the middle of June. At that time the hurdles were all completed for the lengths above given, except that the wattling had not been placed for a length of about 125 feet at the outer end of No. 2½, and for a length of about 60 feet near the shore-end of each of Nos. 6, 6½, 7, and 7½. Large deposits have been secured over the area to be reclaimed. The least depth of channel found in this vicinity since my last report was 10½ feet.

CAIRO.

The mattress, 120 feet wide, to be placed below low-water mark, which at the date of my last report had reached a length of 1,012 feet, was extended down-stream 3,551 feet, making its total length 4,563 feet, when, having reached the limit of any threatened undermining of the bank, it was cut loose from the ways and sunk.

Two smaller mattresses, 100 feet by 30 feet, and 120 feet by 40 feet, respectively, were fabricated and placed between the fifth and sixth of the old spur-dikes. The old protection placed by the Cairo Land Company above the water-surface was re-enforced and repaired wherever it seemed necessary by the deposit of riprap. About 45,556 square feet of surface, extending over 1,158 linear feet of the bank, was covered with stone. Near the down-stream end of the new mattress the slope of the bank was so abrupt that no stone was placed for a length of 650 feet. The revetment seems now to be in serviceable condition, at least for low and medium stages of the river. The balance of the funds available for this work are being held to await the action of

high-water upon the upper portions of the bank, and to raise the down-stream portion of the new work to a higher level, as the bank takes a proper slope by the action of the river.

EQUIPMENT.

Thirteen model barges were built under contract by the Paducah Ship-Yard Company, of Paducah, Ky. Barge No. 20 was run into and sunk by one of the Anchor Line boats, and proved a total loss, and five more of the old barge-flats became unserviceable and were sunk.

FINANCIAL STATEMENT.

A financial statement, including a statement of the expenditures at each locality, for the end of the fiscal year, will be forwarded as soon as practicable after the year closes.

Very respectfully, your obedient servant,

O. H. ERNST,
Major of Engineers.

Col. Q. A. GILLMORE,
Corps of Engineers, U. S. A.,
President Mississippi River Commission.

FINANCIAL STATEMENT.

July 1, 1884, amount available		$525,354 51
July 1, 1885, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1884	$412,494 48	
July 1, 1885, outstanding liabilities	6,286 12	
		418,780 60
July 1, 1885, amount available		106,573 91

Submitted in compliance with requirements of section 2 of river and harbor acts of 1866 and 1867.

Statement showing expenditures for construction, &c., for improvement of Mississippi River between mouths of Ohio and Illinois rivers, Illinois and Missouri, for the fiscal year ending June 30, 1885.

For what expended.	Cash.	Material previously purchased.	Plant.	Liabilities accrued.	Total.
Alton Dike	$9,546 74	....	....	....	$9,546 74
Arsenal Island	10,234 18	$377 66	$1,362 41	$78 31	12,052 56
Cabokia Chute	3,370 07	110 36	420 83	16 95	3,918 21
Horsetail, west side	8,979 37	360 45	1,152 04	45 38	10,537 24
Horsetail, east side	67,413 36	2,330 00	8,405 64	421 91	78,570 91
Twin Hollows, west side	19,589 92	775 80	2,519 63	106 20	22,991 55
Twin Hollows, east side	15,510 23	608 24	1,993 66	79 43	18,191 56
Jim Smith's	134,652 43	4,792 04	16,808 96	684 54	156,937 97
Pulltight	31,246 06	1,115 12	3,787 24	157 61	36,306 03
Cairo Protection	28,501 50	....	....	81 15	28,582 65
Chesley Island	864 03	....	50 15	....	914 18
Thirteen model barges purchased	38,390 60	....	....	....	38,390 60
Pile timber purchased	20,458 08	....	1,706 50	....	22,164 58
Non-payment	251 48	....	....	....	251 48
Extraordinary repairs to plant and value of material purchased and on hand	28,171 50	....	....	....	28,171 50
	417,179 55	10,469 67	38,207 06	1,671 48	467,527 76

Approximate value of plant belonging to the United States and used upon improvement of the Mississippi River between mouths of Illinois and Ohio rivers.

Class of property.	Approximate value June 30, 1885.
1 steamer, A. A. Humphreys	$19,163 45
1 steamer, General Gillmore	18,592 32
1 launch, Florence	709 00
16 barges, model, old	
13 barges, model, new	81,950 00
17 barge-flats	
20 pile-drivers	34,745 44
1 machine shop, floating	1,895 32
1 wharf-boat	141 00
5 quarter-boats	3,775 96
71 skiffs	986 12
48 yawls	1,066 67
119 flats	5,754 07
1 hydraulic excavator	6,773 44
2 ways for mattresses	2,331 00
Tools and appliances	2,513 78
Photographic apparatus	239 51
Office furniture	772 37
Surveying instruments	989 32
Boarding outfit	14,738 29
Total	198,788 41

APPENDIX G.

REPORT OF CAPTAIN SMITH S. LEACH, CORPS OF ENGINEERS, UPON OPERATIONS IN THE FIRST DISTRICT.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., June 18, 1885.

GENERAL: Pursuant to the instructions contained in your letter of the 1st instant, I have the honor to submit the following report of operations for improving Mississippi River, First District, carried on under the direction of the Commission, from October 1, 1884, the date when its progress was last reported to Congress, to the end of the present month and fiscal year.

I relieved Capt. J. G. D. Knight, Corps of Engineers, of the charge of this district on April 14, 1885, at which date all work had been suspended and the force reduced, both in numbers and salaries, to the lowest practicable basis compatible with the safety of the property.

Among those discharged were the assistants in general charge and all but one of those in local charge of the various constructions. In making up this report I have had to rely entirely on the ten-day reports of the assistants. These are, in the main, formal in style and matter, and enable me to chronicle only the progress of the works and their present condition and results. Whatever these gentlemen may have acquired of that higher experience by which errors are avoided and successes repeated has not been recorded.

As no changes in methods of construction are noted in the reports, the presumption is that standard constructions, fully described in preceding reports, were followed to the close.

Materials and supplies were obtained under contracts made at the beginning of the season, and noted in last report. Apart from such contracts, the work was done by hired labor.

GOLD DUST DIKE.

At the date of my last report, October 1, 1884, this system of dikes, consisting of a main or longitudinal dike 2 miles long and seven cross-dikes connecting it with the Tennessee shore, was complete, except a few breaks in the two lower cross-dikes, caused by the high water of January, 1884, and which it had been decided unnecessary to close, and gaps in the main and upper cross-dikes, left for the passage of material. The closure of the latter gaps, with one exception, was in progress and was prosecuted with vigor during the rest of the year. In addition to the new work necessary, the older portions of the main dike were thoroughly gone over and repaired. This portion, built of cottonwood, had been standing over two years, and had greatly

deteriorated in strength by dry-rot, especially of riders and braces. The latter had been broken down in many cases by drift lodging on the dike, and in many others by rotting off. Numbers of them were broken while drawing the new cables, and a tension below the standard had finally to be adopted. Besides these repairs, the closing of the break of 400 feet in the main dike just below cross-dike No. 3, made in the high water of 1883, was completed.

In addition to the pile-work above described, a mattress partly supplied quillage and foot-mats for the new work, and foot-mat in front of main dike for about 5,000 feet, mainly from No. 2 dike down. Part of this was new work and part a widening of old work deemed too narrow.

The expenditures at this point from October 1, 1884, to April 1, 1885, were $38,230.32 inclusive of pro rata of all miscellaneous and general expenses. Expenditures since April 1 have been exclusively for care of property, and although they must perforce appear as part of the gross cost of the improvement, they are not included in making up the cost per unit of various kinds of work. The plant is being maintained in view of future rather than past work, and the cost of such maintenance should properly be charged to future constructions.

It is difficult to reduce such patchy and miscellaneous work to an arbitrary unit. Captain Knight last year estimated the complete and partial work done here to October 1 as equivalent to 38,974 feet of finished dike, and that necessary to complete the system as equal to 1,400 feet. He gave the cost per linear foot of dike at $15.26, of which $1.40 was for repairs, leaving $13.86 as the cost of new work. Adopting these figures, and completing the record to date, there have been constructed 40,374 feet of dike, costing $15.77 per foot, including $1.91 per foot for renewals and repairs.

On January 11, 1885, a break occurred in the main dike, 300 feet above cross-dike No. 3. When first noticed it was 80 feet wide. Within a few days it increased to 250 feet, since when the increase has been little or nothing.* On February 27 a break in main dike 300 feet wide was discovered 400 feet below cross-dike No. 2. This break has not materially enlarged. Both these breaks were thought by the assistant in charge, and apparently with good reason, to have resulted from the weakened condition of the dike, due to rotting of piles and braces. The upper break was precipitated by large masses of ice lodging on the braces as the water fell, and subsequently, after these were broken down, striking the unsupported piles. These two breaks in the main dike, aggregating about 550 feet, have been the only losses sustained by the Gold Dust system during the period covered by this report, so far as could be seen at the lowest stage of water which has occurred.

In general, the deposits within and below this system, since last report, have been constant but slow, as the periods of high water have been short. Locally, great changes have taken place, and of these the fill in the old service channel, closed as above described, may be cited as an example of the astounding results which may be obtained under favorable conditions. This channel, passing through the main dike at its junction with No. 1, was at that point in October last 33 feet deep at low water. It is now dry at 12 or 13 feet above low water, giving a fill of 45 feet obtained in one insignificant rise. This channel is closed to No. 2 dike. Its closure below that point was prevented by the break in the main dike below No. 2, which sent a supply of water obliquely across to the gap in the shore end of No. 3, and thence down Elmot Chute. There has been cut out in the path of this current a channel which will probably discharge at the lowest stage. Water flowing through the lower break in the main dike also contributes to the discharge of Elmot Chute. No change has been noted in the depth of this chute.

PLUM POINT DIKES.

Of this system, intended in connection with closure of Bullerton Chute and the holding of the tow-head to confine the water in crossing Bullerton Bar, a main and six cross-dikes, aggregating 15,000 feet in length, were in progress at last report and had been completed except some mat-work and wiring, principally on Nos. 5 and 6, and bank protection at the roots of the same dikes.

The work mentioned was practically completed in October and November, though a small party worked on the wiring for some time longer.

The expenditures here from October 1, 1884, to April 1, 1885, were $29,576, and resulted in 15,010 feet of completed dike, at a gross cost of $371,108.36, being $24.72 per linear foot.

Nos. 5 and 6 crossed one of the three low-water channels of the previous season, which they were designed to close. During the run of ice the other channels were nearly closed by a gorge, and the effort of the river against No. 5 was correspondingly increased. It was localized at a point where the tip-mat had not been completed, and

* Since the above was written, report has been received of the widening of this gap to 500 feet.

on January 4, 185 feet went out, accompanied by a small gap in No. 6 where it crossed the old channel. The gap in No. 5 has increased to about 250 feet, and another one of 50 feet has been made between it and the outer end. About 100 feet of the extreme end have been worn away, making an estimated total of 400 feet of No. 5 lost.

At the outer end of No. 6, and at a point near the middle, a settling of the dike was observed, the whole structure going down about 5 feet, but remaining erect and intact. This appears to be the first occurrence of this phenomenon, and has not as yet been satisfactorily explained.

Considerable deposits within the limits of this system were noticed before the dikes were completed, and their effect since has been marked, although no rise of any considerable duration has passed over them. The last detailed survey in January showed an average fill of 5 feet over the area inclosed and that affected by the dikes. The latter area is included between the Tennessee shore and a line prolonged in the trend of the outer ends of the dikes, as far down as Yankee Bar. Late reconnaissances show the fill to have continued. Within the dikes it averages probably 15 feet. The Yankee Bar low-water channel has nearly or quite filled up despite the breaks in Nos. 5 and 6.

DIKES TO CLOSE BULLERTON CHUTE.

These comprise Osceola No. 4 and Bullerton Nos. 1 and 2.

At last report Osceola No. 4 lacked about 300 feet of completion. The gap was toward the Arkansas shore, where the river had tried to break into Bullerton Chute. A constant draught of water toward the opening brought considerable quantities of drift, which caused much annoyance. Work was greatly impeded by high and at last stopped by low water. The gap was closed, however, the remaining work being in the rear row of piles. It has stood well and answered every purpose of a completed dike. It has collected a large field of drift and caused a heavy fill above and below it. It has been a valuable protection to Bullerton No. 1, and has contributed in no small degree to the closure of Bullerton Chute, which now appears to be an assured fact.

Dikes 1 and 2 in Bullerton Chute work were completed by the construction of work amounting to about 1,000 feet of dike. The openings had been previously mattressed. In driving No. 1 through the deep water and rapid current of the old channel there was a shortage in the supply of long piles, and to avoid bringing the work to a standstill many sticks of insufficient length and strength were used. In this portion a gap of about 100 feet has been made by drift. It is next the Arkansas shore. The mattress prevented any scour at the opening, and the effect of the gap has probably been to accelerate the deposits in the chute by admitting more water, while it has doubtless retarded the deposits in and below the gap in the Osceola-Bullerton dike by increasing the current there. No. 2 is in perfect condition.

The expenditures on these three dikes, including the slight repairs to Osceola No. 3, were $31,919.89.

Bullerton Chute is rapidly filling up. Full half the area between Nos. 1 and 2 is above extreme low water. Two hundred feet below No. 2 the bottom is nowhere more than 8 feet below the same plane.

FLETCHER'S FIELD REVETMENT.

Since October 1, there have been constructed at this point, in continuation of work and project mentioned in last report, 400 feet of mattress and 2,500 feet of upper bank revetment, involving 2,000 feet of grading. At the close of operations the completed revetment covered 5,343 feet of the bank. There was also 1,100 feet of low-water protection without the corresponding upper bank work. The completed work is in three sections. The lowest one, 800 feet long, near Elmot Landing, was put in for local reasons; a very rapid cave at that point threatening the continuity of the curve of the bend. This work is intact and has fulfilled its purpose. The two sections of the systematic work are separated by nearly a mile. This appears to have been skipped in the first instance to await the removal of sunken timber, which required the efforts of one of the large snag-boats for its accomplishment. The Macomb was loaned for the purpose and the bank was cleared, but at a date so near the close of operations that neither the time nor the money was available to close the gap.

The completed work is in perfect condition so far as visible, and there is nothing to suggest any damage to the subaqueous mattress. A loss of 60 feet at the lower end of the lower section has been reported, due to caving working up from below. It is more probable that this 60 feet has fallen down partly around the false point, and has prevented greater loss.

The expenditures chargeable to this work, including the cost of the snag-boat, are $71,442.87.

REVETMENT OF LOWER OSCEOLA BAR.

Operations at this point comprised the making and sinking of 2,200 feet of mattress and the making of 2,000 feet of complete and 1,200 feet of partial upper bank protection, including 1,500 feet of grading. The close of operations found the bank completely revetted for a distance of 4,500 feet from the head of the bar down, with 700 feet of low water and partial upper bank work below this.

The only injury this work has sustained has been a slide of about 100 feet in length, the middle having gone down about 10 feet and the ends nothing. The cause of this was seepage from ponds left by the falling water. The nearest of these approached within a few yards of the bank, just behind the break, and its water surface was, when first observed, 5 or 6 feet above the river. The sand between the pond and the river was of the consistency of mortar. This pond was drained at a cost of $11, and the sinking was immediately arrested.

Expenditures here were $64,165.88.

REVETMENT OF THE FACE OF BULLERTON TOWHEAD.

This work consisted entirely of repairs to previous work to make good damage caused by seepage. It is noteworthy for the two methods tried, which may be described as a method by draining and a method by bulkheading. The former consists in laying blind drains to dry out the bank as the river falls; the second of a retaining wall of piles and brush built at the outcrops of the water-bearing stratum. Neither has so far failed. The former will be cheaper if found effectual. The assistant retained to care for the property, Mr. A. J. Nolty, had charge of this work. His report is fortunately available for details, and is appended.

The necessity of draining the protected banks has forced itself into consideration through repeated disasters. This appears to be the first serious effort in that direction, and its result is thus far so favorable as to afford strong hope that the last and most insidious enemy of bank revetment will disappear under improved practice.

From the present experience it seems probable that banks of ordinary difficulty can be kept dry with stone drains at a cost of $1 per linear foot.

The expenditures were $19,653.24.

REVETMENT AT CRAIGHEAD POINT.

Work at this point was undertaken in an emergency and under the most unfavorable conditions. The river at a low stage, thrown back from the Bullerton dikes on the one hand and the Plum Point dikes on the other, broke through the bar in a new channel, debouching not more than 1,500 feet from this bank and almost at right angles with it. Violent caving set in and the construction of a mattress in water flowing with a velocity of 7 feet per second was attempted. The results were, unusually large cost of construction and excessive losses during construction. In spite of all difficulties about 1,000 feet of subaqueous mattress and 500 feet of upper-bank protection was in place when a run of ice interrupted, and later exhaustion of funds suspended the work. The subaqueous work seems to have stood, as at the lowest stage its edge was visible at one place, and the caving has been arrested. That it should have done so is entirely beyond reasonable expectation and should not be taken as a precedent for leaving small pieces of work isolated. The little speck of upper-bank work left unprotected on a rapidly caving bank, beset by a violent current, went in at once as a matter of course.

The expenditures at this point were $31,020.

The general condition of the river within the limits of the works remains as at last report, except at Bullerton Bar, where the lower or outside channel of last low water has shifted to a position a little lower down and in prolongation of the ends of the Plum Point dikes. The lower end of the bar which lay off the foot of Bullerton Towhead has followed the crossing down-stream. The bar which formerly joined to the head of Bullerton has been cut through next the towhead, giving about 2 feet less water than the lower way. The crossing from Plum Point to Bullerton Light and between the two described has not changed materially. During a rapid fall of 10 feet in as many days, in the latter part of May, these three routes contested for the honor of the channel. The middle way finally took it with 12 feet at a 12.5 feet stage. The others gave but 8 feet and 10 feet. Such a fall is the most favorable phase for producing obstructions to navigation.

The effects of the different works, as noted in the descriptions of them, do not exactly measure their relative usefulness and value. The Plum Point and Gold Dust system of dikes, for instance, have been laid down on the same plan: that of a main dike run out obliquely from the shore and connected with it by cross-dikes. In development the Plum Point is about 60 per cent. of the Gold Dust system. As regards

the total volume of deposits secured per foot of dike, the two systems may be equally effective. But the Plum Point system was designed to determine and accelerate the formation of a sand-bar under a partially sheltered point, which should restrict the width of the river at lower stages. The deposits induced by these dikes are producing precisely this effect. The system is but one year old, and should its action continue during the rest of its life, with any approach to its past activity, it cannot fail to produce the effect desired. Hence, for such a situation, such a system of dikes may be taken as perfectly successful, and as forming a precedent for constructions under like conditions. The Gold Dust system was designed to close two side channels formed by two islands, and separated from the main river up to the bank full stage. The deposits have been enormous, but they have not been to any great extent in the chutes. They have thrown a barrier across the upper ends, which late experience has shown will be partially broken down whenever a break in the dikes throws a concentrated volume of water across it. The dikes are now beginning to succumb to age, and the chutes though reduced in size are not closed.

Thus these dikes have been but partially successful, and if the results of the last year were continued during the life of another set, the object aimed at would not be reached. These considerations, taken with the gratifying results obtained on the other side by closing dams, strongly suggest that all closures of *high-water chutes* be made by works of small development and extra strength placed at the lower end. The water bearing the coveted sediment must enter at the upper end, and the portal should be kept broad and inviting to the last moment.

The present standard dike, considered simply as a structure designed to meet certain strains with a maximum of effect at a minimum cost, seems everything that could be desired. In bank protection, by the method of continuous revetment now in use, the great desideratum is that the work shall be complete; that is, that it shall, in one working season, be extended from a point above the cave to a point below it. To leave an end exposed on a bank likely to cave, or leave an unprotected upper bank over a subaqueous protection, is to invite destruction. In cases of absolute necessity the former risk is to be preferred.

Later improvements in this class of work have been principally in the direction of increased longitudinal strength. Recent experience furnishes a number of instances in which such strength has limited to a fault what otherwise would have been a break, which always means a loss. A more thorough system of anchoring to the bank is also desirable. Work of this class on this reach has suffered a very small percentage of loss, despite the fact that it has invariably been done in defiance of the two most important conditions of success—enough money to complete it, and plentiful and timely supplies of material. The one is the principal cause of loss to work in place, and the other of losses during construction. The latter, it may be remarked, needs only a sufficiency of steamers and barges to eliminate it from the problem.

There is submitted herewith a report by Assistant Engineer A. J. Nolty, who had immediate charge of the repairs to Bullerton revetment and the two Bullerton dikes. In order to present all the information attainable, he has, at my suggestions, added his observations of the other works and some data as to their original extent and present condition.

The following financial statement and balance sheet exhibit the financial condition of the district:

APPROPRIATION FOR IMPROVING MISSISSIPPI RIVER, ACT OF JULY 5, 1884, FIRST DISTRICT.

Financial statement.

Balances on hand October 1, 1884, as per last report:		
Plum Point Reach		$320,243 88
New Madrid Reach		2,141 09
Saint Francis Front		126 89
		322,511 86
Expended from October 1, 1884, to June 15, 1885	$299,756 23	
Estimated liabilities to June 30, 1885	5,225 00	
		304,981 23
Balances, June 30, 1885:		
Plum Point Reach	15,265 65	
New Madrid Reach	2,138 09	
Saint Francis Front	126 89	
		17,530 63

GENERAL BALANCE-SHEET.

Improving Mississippi River, First District, Plum Point Reach.

DR. | CR.

Mar. 3, 1881	To allotment	$568,095 18	Mar. 1, 1884	By expenditures of secretary of Construction Committee from Plum Point allotments, to date	$430,095 18
Aug. 26, 1882	......do	700,000 00	Apr. 1, 1885	By expenditures of secretary of Construction Committee from allotments for general service, to date	79,049 23
Apr. 14, 1883	.. do	300,000 00	June 15, 1885	By expenditures of district offices, to date, as per voucher books	1,859,529 85
Sept. 7, 1883	To cash collected	20 00	June 30, 1885	By liabilities	5,225 00
Nov. 23, 1883	To allotment (transfer)	10,000 00	June 30, 1885	By balance	15,265 05
Dec. 10, 1883	To allotment	67,000 00			
Mar. 4, 1884	To allotment, less subsequent transfers	365,000 00			
Aug. 2, 1884	To allotment	300,000 00			
Apr. 1, 1885	To general service, charges to date	79,049 23			
		2,389,164 41			2,389,164 41

Improving Mississippi River, First District, New Madrid Reach.

DR. | CR.

Aug. 2, 1882	To allotment, less subsequent transfers	$212,500 00	Mar. 31, 1885	By expenditures of district offices, to date	$4,558 60
			Mar. 31, 1885	By expenditures of secretary of Construction Committee, to date	205,803 22
			June 30, 1885	By balance	2,138 18
		212,500 00			212,500 00

Improving Mississippi River, First District, Saint Francis Front.

DR. | CR.

Dec. —, 1882	To allotment	$5,000 00	Apr. 1, 1885	By expenditures of district officers, to date	$4,873 11
			June 30, 1885	By balance	126 89
		5,000 00			5,000 00

There are appended hereto tables of classified expenditures and value of plant.

Very respectfully, your obedient servant,

SMITH S. LEACH,
Captain of Engineers.

General Q. A. GILLMORE,
President Mississippi River Commission.

Distribution of expenditures on Plum Point Reach, May, 1881, to March 31, 1885.

Locality.	Proportion of general expenses.	Subsistence.	Surveys.	Care of property.	Steamers.	Office and general administration.	Labor on construction.	Construction and outfit of plant.	Material for construction.	Miscellaneous.	Total.
Ashport	109	$2,694 59	$358 95	$1,024 93	$4,333 84	$516 33	$4,989 26	$6,685 73	$5,139 02	$224 00	$25,966 65
Gold Dust	2,673.5	66,090 59	8,802 89	25,134 91	106,282 57	12,663 18	122,353 20	163,950 37	126,023 51	5,453 05	636,754 27
Fletcher's Field	700	17,294 70	2,305 10	6,582 70	27,833 40	3,315 90	32,041 10	42,935 90	33,002 90	1,438 10	166,749 80
Osceola Upper Dike	133	4,771 15	635 56	1,814 78	7,674 07	914 24	8,834 18	11,838 04	9,099 33	396 63	45,977 98
Osceola Middle Dike	194.5	4,808 23	640 51	1,828 88	7,733 71	921 34	8,902 84	11,930 04	9,170 09	399 70	46,335 34
Osceola Cross Dikes, 1, 2, 3, 4	695	17,181 09	2,288 63	6,535 08	27,634 59	3,292 21	31,812 24	42,629 21	32,767 16	1,418 22	165,558 43
Osceola Upper Bar	107	2,645 15	352 36	1,006 12	4,254 53	506 86	4,897 71	6,563 06	5,044 73	219 88	25,490 40
Osceola Lower Bar	667.4	16,498 80	2,196 74	6,275 56	26,537 15	3,161 47	30,548 90	40,936 31	31,465 91	1,371 50	158,992 34
Bullerton Main Dike	372	9,196 21	1,225 00	3,497 92	14,791 46	1,762 16	17,067 56	22,817 37	17,538 68	764 46	88,620 82
Bullerton Cross Dike No. 1	394	9,740 07	1,297 45	3,704 78	15,666 23	1,866 38	18,034 56	24,166 78	18,575 92	809 67	93,861 84
Bullerton Cross Dike No. 2	290	7,169 09	955 00	2,726 87	11,531 00	1,373 73	13,274 17	17,787 73	13,672 63	596 00	69,086 22
Bullerton Tow-head	1,060	26,204 26	3,490 68	9,963 18	42,137 72	5,021 22	48,509 38	65,007 22	49,965 82	2,168 30	252,467 78
Plum Point Dikes	1,558	38,505 34	5,130 60	14,649 87	61,939 20	7,380 25	71,304 33	95,553 05	73,445 03	3,200 69	371,108 36
Craighead Point	262.5	6,489 26	864 40	2,468 28	10,437 52	1,243 46	12,015 41	16,100 96	12,376 08	601 08	62,596 45
Totals	9,275.9	229,288 53	30,543 87	87,213 86	368,786 99	43,938 73	424,544 84	568,901 77	437,286 81	19,061 28	2,209,566 68

NOTE.—The above table of classified expenditures was prepared under the direction of my predecessor, Captain Knight and represents the state of affairs at the close of his administration of the work. Late experience has suggested a revision of the pro rata of distribution of indirect expenses, as a result of which some works, on which nothing has been spent in the interim, appear in this table with a slightly less cost than was assigned them in last report.

Expenditures from April 1 to June 30, are: For care of property, $8,830.25, including liabilities of $1,760; for surveys, $2,331.18, including liabilities of $225.

Approximate value of plant belonging to the United States, and used upon the improvement of the Mississippi River, First District.

Class of property.	Number.	Approximate value June 30, 1885.
Steamer P. Kirns	1	$7,769
Steamer Itasca	1	8,617
Steamer Abbot (new)	1	4,970
Launch Titania	1	1,099
Pile-drivers	37	123,873
Quarter-boats	15	25,704
Mattress-boats	10	27,898
Graders	2	38,814
Derrick-boats	2	5,559
Barges	51	46,821
Machine-shop boat	1	5,303
Whitehall boats	8	280
Skiffs	63	765
Tools and appliances	....	10,000
Office furniture	....	100
Surveying instruments	....	200
Total value	....	307,772

G 1.

REPORT OF ASSISTANT ENGINEER A. J. NOLTY UPON OPERATIONS IN THE FIRST DISTRICT.

UNITED STATES ENGINEER OFFICE,
Sans Souci, Ark., June 9, 1885.

SIR: I have the honor to herewith submit my report of operations at Bullerton Towhead, in Bullerton Chute, and at various other places on Plum Point Reach, for the period beginning October 1, 1884, and ending June 30, 1885.

At the beginning of this period there were six construction parties in the field, viz: Mattress and revetment party at Fletcher's Field Bend; mattress and dike party at Gold Dust; mattress and revetment party at Osceola Bar; mattress and dike party at Plum Point, mattress and dike party at Bullerton, and a mattress and revetment party at Craighead Point Bend.

Work on Craighead Bend bank was started during the first week in September, by beginning the construction of a foot mattress 175 feet wide, and by clearing the bank of timber and drift preparatory to grading and revetting it. From the nature of the soil composing the bank of this bend (silt and sand), the depth of water, averaging 43 feet below low water of 1879, the velocity of the current from 6 feet to 7 feet per second and the rapid caving of the bank, it was at once evident that it would be no easy undertaking to successfully revet this bank. These apprehensions were fully realized as the work progressed. At the beginning of the period 581 feet of mattress 175 feet wide was lying afloat at this place when the accumulation of drift, brought down by a previous rise in the river, broke it loose, parting twelve 2-inch lines. The mattress lodged below the point and was a total loss. After the rise had subsided and the river became clear of drift a new mattress was begun, and 660 feet constructed when a coal barge, laden with staves, struck the head of it. Though the mattress was not injured by this collision, it was accepted as a warning to get it down, and accordingly the piece was sunk, the operation of sinking being successfully accomplished. While this mattress was being constructed the bank in front of it had in the mean time caved so far from its inner edge as to necessitate the construction of a supplementary mattress 50 feet wide to connect the main mattress with the proposed revetment. While this construction was going on the bank was being graded and revetment laid thereon. For grading a hydraulic grader was at first used, but owing to the nature of the soil it was found entirely unsatisfactory. Wooden sluice boxes were then constructed, a cut representing the slope of bank was made into the soil the sluice running from top to foot of bank placed in this cut and the dirt shoveled into it by the men washed was down by means of a pile-driver pump. This plan worked, very well and gave good results both as regards nature of work and cost. Work was continued thus with varying success until about 900 feet of bank had been protected, when the ice coming down put a stop to all further operations there, and by the time the river had become clear of ice, orders had been received to stop all work on the

reach. The work as far as could be seen had been done in good style and in a conscientious manner by Assistant Engineer Yeager. Yet by the end of February not a vestige of the high-water bank protection was visible and the bank is now caving and sloughing off as bad as previous to beginning of work. Examination of this bank where caving is going on will show that it is mainly caused by that old enemy to revetment work, namely, seepage. No data is at hand from which to compile the amount of material expended on, or the cost of this work.

At Bullerton Tow-head repairs to revetment of outside bank damaged by seepage were being made at the beginning of the period. Here two different plans suggested by experiments carried on during the summer were practically applied. One method was as follows: A trench, 90 feet long, 4 feet wide at bottom, and 16 feet deep was dug from the foot of the bank back. This trench was filled to a depth of 6 feet with stone, and the whole again covered up. The damaged bank was then graded to an easy slope and revetment laid thereon. The piece of bank chosen for the application of this method was at that time sloughing off badly and the semi-liquid material running into the water. So soft was this material a few feet below the top that a stone or piece of drift-wood thrown down would sink out of sight. As soon as the drain was put in a marked change became at once visible. Water ran out of the drain in a small but continuous stream, and the bank on both sides began to dry up rapidly; the drainage influence extended for about 35 feet from the mouth on either side. No damage has occurred here since. The other method which was tried at two different places is as follows: Two rows of piles, 12 feet apart and parallel to the line of bank, were driven, the piles of each row 4 feet apart. The first, or inner row, was driven about equi-distant between the water-line on the bank and the foot of under-water slope. The space included between the two rows of piling and between the foot of graded bank and first row was filled up to water-surface with brush mattresses 3 feet thick and of requisite width, each mattress being sunk independently of the overlying one. The whole structure was well braced, tied, and anchored, and the above-water portion of bank revetted in the usual manner. Unfortunately, owing to insufficiency of stone and brush, only one of these retaining dikes could be finished, the other and much longer one being only partially and its own piece of above-water bank being entirely unprotected. The finished piece looks perfect to date, and the other, though the bank is entirely bare, has undergone no change whatever. With the exception of the unfinished piece of work first mentioned, which is 300 feet long, the outside bank of Bullerton Tow-head is completely protected and the work in good shape.

In Bullerton Chute Cross-dikes No. 1 and 2 were completed by the end of 1884, except that nearly 900 feet of tipped mat remained afloat, owing to lack of stone for sinking. Preparations had been made to take stone off Bullerton Tow-head and other heavily loaded revetments, but before any was received the river had risen high enough to entirely submerge the dike. At a subsequent subsidence of the water a barge-load of brick was distributed over this mat, without, however, accomplishing much good. The brick, in the first place, were badly baked, being hardly more than sun dried, and soon crumbled under water.

Their specific gravity being very low it required a large number of them to sink a given piece of mat, and as the brick were badly broken up and the mat not woven close enough for such ballast, the bulk of the brick passed through the interstices of the mattress. Even under the most favorable conditions of brick and mattress it is safe to assume that $1 worth of stone will accomplish as much as $6 of brick. In closing the gaps in Nos. 1 and 2—necessarily left open until the works above these dikes were finished, as all towing had to be done through them—much trouble was encountered from difficulty in handling and holding the drivers. These gaps were left in the line of deep water: and as the dikes advanced from either side the already strong current increased considerably; several times in lowering piles the drivers were broken loose either by the lines parting or the piles or kevels to which they were fastened breaking off. The greatest retardation the work suffered from was due to failure to receive material as required. Notably was this the case with piling, as not only was the supply insufficient but the kind furnished was very poor. In closing gap number 1 while working in 40 feet of water, only poor cottonwood piles of from 50 feet to 58 feet in length were available. These the assistant in charge was compelled to use as the flood season was approaching and his orders were to close the gaps before high water drove him out. To compensate in a measure for the lack of strength in the individual piles an extra row of piling was added at this place. While closing this gap it was noticed that after the piles had penetrated the foot mattress they would drop down about 6 feet before meeting with any resistance. This phenomenon was noticed for a distance of 40 feet in the first, second, and third rows, but only slightly in the latter, while in the fourth and fifth it was not felt at all. Careful soundings revealed the existence of a deep narrow trough or gully at the bottom, to which the stiff mattress could not accommodate itself, but simply bridged it over. As the down-stream half of this mattress width rested well

on the bottom it was presumed that this hole would soon fill up. This seems to have taken place not however until the first and second rows had settled down about five feet, still, however, retaining their vertical position. The explanation offered for this action is that as the piles were too short to give more than about 14 feet penetration through mattress the actual penetration in the river bottom was only about 6 feet, this into sand which probably scoured out down to the clay stratum, the mattress acting as a guide and the rear portion of the dike as stays to keep the sinking portion vertical. No further change was noticed, and as a heavy fill has now taken place all along this dike no damage is expected. When the ice began running in the early part of January, 1885, the entire chute above number 1 was blocked solidly with ice, bringing a great pressure to bear against this dike. Upon the river falling sufficiently to expose this work it was noticed that where the short and weak piles had been used the dikes had been forced out of perpendicular for about 50 feet. The water rose again and soon after subsidence and exposure of the dike showed that part broken down. No further damage has taken place here and the gap is too small to retard, fill, or otherwise injure the work. Dike No. 2 is in fine condition with a vast field of drift in its front. It is recommended that when the river falls sufficiently to admit of doing so the tipped mattress at this dike, not yet sunk, be so disposed of as it will then, by checking what little current comes through the chute, induce a more rapid fill. About 200 feet of this mat next the Arkansas bank should, however, for sanitary reasons be left afloat while the fleet is laid up behind there.

While the work in Bullerton Chute was in progress, an examination of Osceola Dike No. 4, which is next above Bullerton No. 1, revealed a weak place in the Arkansas end, which demanded immediate attention. Two pile-drivers were therefore detached from the Bullerton work and sent up to the damaged dike to reinforce it, which was accomplished by driving 200 feet of partly two and partly three row dike behind it. This has enabled the dike to resist the pressure against it, caused by the immense accumulation of drift in its front, and this work has since sustained no damage.

When Osceola No. 4 was under construction, and before more than the first row of piles had been carried over the then submerged sand-bar, the water fell and the drivers had to be withdrawn from work at that place and pushed out into deeper water, there to continue work. It was not until January that the stage of river was again high enough to admit working on the uncompleted portion, and work was continued then until the water rose so high as to seriously endanger the drivers by the probable loosening of the drifts in front, when work was finally abandoned, leaving about 100 feet of three-row uncompleted, but still strong enough to remain until next season. The work at Bullerton Tow-head, in Bullerton Chute, repairs to Osceola Dike No. 4, have been in charge of Assistant Engineer Nolty.

The work at Plum Point consisted in construction of cross-dikes Nos. 4, 5, and 6, extensions of main dike, and construction of foot and tipped mattresses. At the close of the season all the cross-dikes had been extended as far out as the plans of the work called for, and the main dike or training-wall carried down to cross-dike No. 3. In the prosecution of these works much difficulty was caused by the depth of water and velocity of current, especially in extending cross-dikes Nos. 5 and 6 to the required distance out. This work has been in charge of Assistant Engineer Hatfield. At Lower Osceola Bar the work consisted in revetment of outer bank and repairs to old revetment around its head. The grading of the bank here was done with one of the hydraulic graders. Foot mattress constructed here was 150 feet wide. No trouble was encountered here during construction except when drift was running; as at all other works much delay was caused by insufficient supply of material. When the ice began running a large amount of revetment was without any ballast, and as word was received from Captain Knight not to expect any more stone, arrangements were made as soon as the river was somewhat clear of ice to take 25 per cent. of the stone from the finished work and distribute it over the unballasted part. This work has been in charge of Assistant Engineer Seddon.

At the Gold Dust system of dikes work on main and cross-dikes, consisting of new and repairs to the old work, was continued during the period up to the final cessation of work. This system of dikes has always been more difficult to maintain than any other on this reach. Various causes have operated in opposition to this work. Unlike the Plum Point system, this is not protected by a projecting point in the bank which has a tendency to deflect the main current away from the work, but has a straight reach above it, and before the contraction works were put in nearly 50 per cent. of the volume of the river sought a passage through the chutes now closed up. Much work was done here in the early days of the improvement works, and was not built as strong as after experience taught us it must be. Hence there occurred frequent breaks in this old work, which were always closed with much more stable construction, until now very little of this former work is left. The work at Gold Dust has been in charge of Assistant Engineer Geuder, ably assisted by Superintendent Riley.

At Fletcher's Bend work on bank protection was continued by three different parties at as many different sites. Work was pushed to the utmost here, the aim being to, if possible, finish the revetment of this rapidly caving concave bend before the bevent of the flood season. Had the river remained free from ice, the worst part of the bank at least would have been entirely protected; but the heavy flow of ice necessitated stoppage for several weeks, and by the time ice stopped running, orders were received for a discontinuance of all work, owing to failure of Congress to make an appropriation. All that could be done after these orders were received was to borrow stone from finished works and put enough on the new, yet unballasted work here, to hold it down. The work here is now in two sections, separated by 5,000 feet of entirely unprotected and now caving bank. Snag-boats Meigs and McComb were used here to remove snags and submerged timber in the line of foot mattress. The latter boat was employed only for a short time on such snags as were too heavy for the former to remove. A new method of loading revetment was tried here and found to work well and economically. A pile-driver was laid on the outside of the stone barge and a three-fourths inch wire rope run from the leads at a convenient distance above deck to trees or stumps on the bank, and then fastened. Upon this rope a traveler, having pendent to it a stone-boat capable of containing one cubic yard of stone, was made to run and by means of a hauling line operated by a steam winch the stone was hauled to place and dumped, the empty boat descending by gravity. A few men could distribute the stone evenly as fast as it was dumped. The work at this station has been under charge of Assistant Engineer Gould. The removal of the fleet to the winter harbor in Bullerton Chute was begun the latter part of December, 1884, and continued as fast as plant was put out of commission, until ice in the river prevented all towing. As soon as the ice flow ceased, towing was resumed and continued uninterruptedly until March 15, by which time all plant had been removed.

The force which had already been greatly reduced in number was still further reduced as soon as the plant was all collected. All the assistants except one were discharged, and the permanent fleet party, numbering thirty-five all told, organized. For reasons of economy it was decided by the officer in charge to send up the fleet of the second district to be consolidated with that of the first. The first installment of this plant was received from United States steamer Minnetonka on the 25th of April, and by the 29th all of that plant was up here.

In the mean time it became apparent that where the first district fleet was laid up, *i. e.* along the inside of the Bullerton Tow-head, just below Bullerton cross-dike No. 2, steady fill was going on, and that there would not be sufficient water during the low-water season to float all the plant. It was therefore decided to move everything over to the Arkansas bank, where there was, and still is, deep water. This moving over of the first district as well as moving up of the second district fleet (this latter plant had been tied up along Arkansas bank, but low enough down so as not to interfere with the final arrangement of the whole fleet) was done with the launch H. L. Abbott and tug Itasca, and accomplished in about eight days. The fleet, as finally arranged, extends 4,072 feet along the Arkansas bank of Bullerton Chute, the head of the fleet being far enough below Dike No. 2 to allow the regular mail packet to approach the Sans Souci landing. The fleet, numbering 181 pieces, is divided into three sections, each being five pieces abreast, and connected to the succeeding one by a floating bridge 200 feet in length, this bridge being the continuation of the center line of barges which are all flush-decked ones, and form a convenient footway from end to end of the fleet. The first section is composed of such barges as have no cabins thereon, the second of pile-drivers exclusively, and the third of quarter-boats, steamers, graders, and other plant having cabins upon them. The principal danger to be apprehended is from fire, and the utmost care and vigilance are exercised to prevent an outbreak. The means for combating fire, should any occur, are, it is believed, complete, and consist in a judicious distribution of hand fire-grenades all over the fleet, filled water-barrels and fire-buckets on the decks and roofs of all cabin boats, an organized fire department with an experienced chief, and an excellent fire-boat capable of throwing two 1¼-inch streams, upon which steam is kept up night and day. To prevent loss of portable property, it has been collected from the different pieces and stored in various quarter-boats and put under lock and key; special watchmen have been assigned to these boats, whose principal duty is to care for and protect this property. The harbor now occupied by the fleet is an excellent one, having a least depth of 5 feet below low water of 1879. This lowest water being at the head is well protected by the dike against drift and ice, is secure against violent storms coming from any direction except southeast, being land locked on three sides, and has fixed banks the entire length of the fleet. No rapid filling up is indicated here, the water parting with most of its sediment above Dike No. 2, and the lead bringing up only soft mud when soundings are taken along the fleet. A large amount of property remains stored on the bank at Elmot, some in the open air, and the more valuable and perishable kind under shelter. A trusty watchman is in charge of it. Condemned quarter-boat

No. 3, blocked up on the bank at Elmot, and used as a store-house, was, with most of its contents, destroyed by fire during the night of April 1. Loss estimated at $5,000

The following table shows amount of work done at the various stations on this reach for the period:

At Gold Dust:		
Foot mattress made	squares..	3,191
Foot mattress sunk	do....	2,928
Tipped mattress made	do....	718
Tipped mattress sunk	do....	718
Brush cut	cords..	302
Dike completed	linear feet..	1,645
At Fletcher's Bend:		
Foot mattress made	squares..	1,845
Foot mattress sunk	do....	3,279
Bank graded	linear feet..	500
Revetment made	squares..	2,967
Revetment loaded	do....	3,400
Snags removed	linear feet..	3,000
At Osceola Bar:		
Foot mattress made	squares..	3,418
Foot mattress sunk	do....	4,370
Revetment made	do....	3,909
Revetment loaded	do ...	4,200
Bank graded	linear feet..	2,586
Ditching	do....	200
At Plum Point:		
Foot mattress made	squares..	650
Foot mattress sunk	do....	650
Tipped mattress made	do....	1,974
Tipped mattress sunk	do....	1,974
Revetment made	do....	150
Revetment loaded	do....	150
Dike completed	linear feet..	900
At Bullerton Tow-head and in Bullerton and Osceola chutes:		
Foot mattress made	squares..	1,223
Foot mattress sunk	do....	920
Revetment made	do....	384
Revetment loaded	do....	384
Tipped mattress made	do....	150
Tipped mattress loaded	do....	420
Bank graded	cubic yards..	9,500
Brush filling	do....	3,036
Drains constructed	linear feet..	100
Dike completed	do....	3,012
Brush cut	cords..	134
At Craighead Point:		
Foot mattress made	squares..	2,093
Foot mattress sunk	do....	1,544
Bank graded	cubic yards..	33,618
Revetment made	squares..	338
Revetment loaded	do....	338
Drains built	linear feet..	282

In addition to the tabulated work given above a great deal of work was done by the different parties which cannot be properly classified.

PRESENT CONDITION OF THE WORKS.

The condition of the works on the reach at date is about as follows: In Ashport Bend the bank has been protected from the mouth of Forked Deer River to Ashport Landing, a distance of about 3,000 feet. No work has been done here since 1882. Bank from foot of this revetment down to Gold Dust Landing caving badly. The Gold Dust contraction works were completed as projected, and both Chute No. 30 and Elmot Chute would be practically closed up, were it not for the breaks, which occurred during construction and after completion of the system, both in main and cross dikes.

These breaks, of which there are two in main dike, aggregating in width about 800 feet, and in the cross-dikes aggregating 3,500 feet in width, still allow a large volume of water to pass through these chutes. The suggestion is here respectfully offered that

only the breaks in the main dike be closed by building around the deep water now crossed by a line joining the ends of these gaps and extending back 100 feet inside this line; that the breaks in the cross-dikes be ignor d, and in lieu thereof a strong dike be thrown across from Elmot Bar to Island No. 30 on Range 36, and one from the latter island to the Tennessee bank, at about Range 38. The aggregate length of these two dikes would not exceed 1,800 feet. Experience in Osceola and Bullerton chutes has shown that such cross-dikes are more easy to maintain, and will effectually turn the water. Such dikes would also check the caving now going on along the bank of Elmot Bar and Island No. 30. Of course no dike-work should be put in here or anywhere else until the site of such work is first well mattressed.

In Fletcher's Bend the bank protection extends now from near the mouth of Mill Bayou down 2,875 feet. From the foot of this work about 5,000 feet down, the bank is entirely unprotected and caving badly; another section of revetment begins here, running down 1,480 feet and at the foot of this section we strike again the caving bank.

Lower down at Elmot is another section of revetment 750 feet long, the construction of which was necessitated by a suddenly developed tendency of the bank to cave. The bank between the foot of the first and the head of the second section of revetment, and from the foot of this down some distance, is heavily timbered up to the edge of bank, and no doubt when work is resumed the first steps here will be to remove the snags and submerged timber. This timber falling into the river may have a tendency to check caving, and thus lessen the danger which now threatens this second section. At present the chances are decidedly against saving any part of the threatened work. All the works at this section are in first-class condition, except at the extremities of section No. 2, which have to some extent followed the caving bank. Osceola Chute is completely clo-ed and rapidly filling up; all the work here is in good condition. The three principal cross-dikes have vast masses of drift in front of them; that in front of Nos. 1 and 3 being well covered with soil and vegetation.

At Upper Osceola Bar no high-water bank protection is visible; what little of this work that was put there during the early spring of 1883, when the river was quite high, having all slid down. The entire bar has a foot mattress in front of it, and not much caving has occurred here; still this work should be finished as the channel now runs along there.

At Lower Osceola Bar the bank is protected on the outside for 4,339 feet from the head down and around the head down the inside bank to Osceola cross-dike No. 3, a distance of 1,000 feet.

This work stands well, the only damage it sustained having been caused by seepage from some ponds in the rear. These ponds were drained, and no further damage has been sustained. The damage is very slight, consisting of a sliding down of the revetment for 100 feet, the greatest width of bank exposed being 15 feet. Below the revetment the unprotected bank is caving to some extent. At Plum Point when the work ceased the condition of it was as follows: All the cross-dikes, six in number, extended out as far as the plan of the work required. The main or training dike had been carried down to cross-dike No. 3. One break 250 feet wide had been made in cross-dike No. 5, and one 200 feet in No. 6. Since then No. 5 has been shortened about 500 feet by additional loss, and another break in No. 6, nearly 300 feet long, is visible. All the other work is perfect, and heavy fills are apparent. Yankee Bar is still caving in at the head and a large volume of water goes through the breaks and down between Yankee Bar and the Tennessee bank.

At Bullerton Tow-head the entire outside bank, 9,625 feet in length, with the exception of 300 feet, is protected. The 300 feet lacks the high-water protection.

The protection works run around the head and down the inside bank for 500 feet. The bank appears perfect as far as finished and no damage is visible even at the unprotected part of the bank.

In Bullerton Chute a small break, 75 feet long, has been noticed in cross-dike No. 1, due to the poor piles used here. This gap does not appear to be of any consequence and has not increased in width since first noticed last winter. Cross-dike No. 2 is in perfect condition with an immense accumulation of drift in its front. Heavy fills are noted between Nos. 1 and 2, and above the former. At Craighead Point all the revetment put in has disappeared. The foot mattress, however, is evidently doing some good in preventing the caving, which below it is very serious. At Gold Dust there are now stored about 1,600 cubic yards of stone received after the close of operations. Since the close of operations a regular system of periodical inspection of work, and of soundings and velocity measurements over the more changeable portions of the reach, instituted by you, has been conducted. The latter data are yet too meager and obtained at too high a stage of river to justify me in venturing any prediction as to the ultimate results of the completed work, or the final location of the low-water channel. Valuable information has been obtained and the notes taken are carefully collected and preserved for further reference and comparisons. Your attention is again respect-

fully called to the destruction of large quantities of willows on Osceola Bar by private parties, who claim that they have entered the land there and are cultivating it. A rumor has reached me that parties are contemplating taking possession of other tow-heads, no doubt with a view of charging high prices for needed material when such is wanted; some of the branch ditches cut at Osceola Bar to lead the water into the main ditch have been plowed over and practically closed. Such actions strongly point to the necessity of legislative enactment, whereby the control of these lands is given entirely to the commission and its officers.

Respectfully submitted.

AUG. J. NOLTY,
Assistant Engineer.

Capt. SMITH S. LEACH,
Corps of Engineers, U. S. A.

APPENDIX H.

REPORT OF CAPTAIN SMITH S. LEACH, CORPS OF ENGINEERS, UPON OPERATIONS IN THE SECOND DISTRICT.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., June 18, 1885.

GENERAL: Pursuant to the instructions contained in your letter of the 1st instant, I have the honor to submit the following report of operations in the second district, Mississippi River, from October 1, 1884, the date to which progress was last reported to Congress, to the end of the present month and fiscal year.

I relieved Capt. Clinton B. Sears, Corps of Engineers, of the charge of this district on March 10, 1885. At that date all operations were suspended and the force reduced to that absolutely required for routine office work and care of property.

MEMPHIS REACH AND HARBOR.

On this work the assistant in charge, Mr. W. M. Rees, had been retained, and I am able to submit herewith his report, giving full details of the work with which he has been associated from the beginning, and of which he has a knowledge which can only be gained by such association. (See Appendix H 1.)

The work on the Memphis reach has been entirely for bank protection. That on the Memphis Levee, from the magnitude of the local interests involved, was brought up in grade very much above anything yet attempted when navigation alone was at stake. The gravity of the situation also forbade the beginning or prosecution of the work under unfavorable conditions, and the more adequate supply of plant prevented serious distress from lack of material. Under these circumstances a work was constructed very much superior in strength and completeness to any heretofore done on the river, and at a cost not exceeding that of some inferior work, attempted elsewhere under adverse conditions, and harassed by lack of material during construction. If protection of the caving banks of the Mississippi River will justify an expenditure of $25 per running foot, a revetment like the one in question can be put down for that money and will do the work. This with the proviso that no piece of work be undertaken until money and material to complete it are in sight.

The work in Hopefield Bend has stood well. The only loss to be reported is that of some 2,000 feet of partial upper bank work put in in 1883. Its top edge was against the foot of a bluff bank 10 feet high. It was intended to complete it before the close of operations last season, but the sudden rise prevented. The full work of last season has been damaged in four or five places by the development of faults or slides down the bank.

The continuity of the work appears not to be broken, nor is the bank allowed to cave, but of course the probability of a break is much increased by these slides. They are probably due to the softening of the foundation of the mattress by sipe-water. The semi-fluid mass acts as a lubricant and allows the mat to slide. Drainage and anchoring to the bank will meet this difficulty.

LEVEES.

The only levee work done in this district during the past fiscal year has been the repair of the Long Lake Levee from Old Town, Ark., up.

From the last appropriation $15,000 were allotted for the repair of this levee, provided "the district officer, upon examination of such levee, shall find its condition to be such as to require such repairs for its safety; and provided also, that said sum shall not be expended until the levee from Helena to the upper end of Long Lake Levee shall be first, and prior to November 1, 1884, repaired and completed to a grade 2 feet above the flood of 1882."

These conditions having been complied with, it was decided by Captain Sears, the district officer, to begin the repair work at the lower end, where there were a number of large gaps and a scanty population, and work up-stream as far as the allotment would permit. He thought the large population behind the upper end of the levee would for its own safety strengthen this portion. Proposals for this work, amounting to some 60,000 cubic yards, were advertised October 25, 1884, bids were opened November 5, 1884, and the contract was awarded to the lowest bidders, Messrs. Winters & Cooney, at 23 cents per cubic yard.

Work was begun immediately and finished in March, 1885.

The whole allotment was expended in engineer's expenses, inspection, and contractors' estimates.

The following financial statement and general balance-sheet show the condition of allotments and expenditures for this district:

APPROPRIATION FOR IMPROVING MISSISSIPPI RIVER, ACT OF JULY 5, 1884, SECOND DISTRICT.

Financial statement.

Balance on hand October 1, 1884, as per last report:		
Memphis Reach and Harbor		$183,327 03
Long Lake Levee		15,000 00
		198,327 03
Amounts received since:		
On account of sale of fuel	$33 75	
On account of overpayment	281 81	
		315 56
		198,642 59
Expended from October 1, 1884, to June 15, 1885:		
Memphis Reach and Harbor	180,333 03	
Long Lake Levee	15,000 00	
Total expended	195,333 03	
Estimated liabilities to June 30, 1885	1,750 00	
		197,083 03
Balance June 30, 1885 (Memphis Reach and Harbor)		1,559 56

GENERAL BALANCE-SHEET.

Improving Mississippi River, Second District, Memphis Reach and Harbor.

Dr.				Cr.	
1882.			1884.		
Aug. 2	To allotment	$325,000 00	Feb. 29	By expenditures of secretary of Construction Committee from Memphis, allotments to date	$167,009 22
1884.					
Jan. 18	......do	90,000 00			
Feb. 29	To deposit, sale of fuel	9 22			
July 5	To allotment	200,000 00	1885.		
Oct. 31	To deposit, sale of fuel	11 25	April 1	By expenditures of secretary of Construction Committee, from allotment for general service to date	54,870 89
Dec. 31	......do	11 25			
1885					
Jan. 26	...do	11 25			
Feb. 6	To overpayment refunded	281 81			
April 1	To general service charges to date	54,870 89	June 15	By expenditures of district officers to date	445,006 00
			June 30	Estimated liabilities to date	1,750 00
			June 30	Balance	1,559 56
		670,195 67			670,195 67

Improving Mississippi River, Second District, Long Lake Levee.

)R.					CR.
385. y 5	To allotment	$15,000 00	1885. June 30	By amount expended by district officers	$15,000 00

A table of value of plant is appended.

Expenditures classified as far as the present condition of the records admits will be und in Mr. Rees's report.

Very respectfully, your obedient servant,

SMITH S. LEACH,
Captain of Engineers.

General Q. A. GILLMORE,
President Mississippi River Commission.

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proximate value of plant belonging to the United States, and used upon the improvement of the Mississippi River, Second District.

Class of property.	Number.	Approximate value June 30, 1885.
amer H. M. Graham	1	$4,650 60
unch Daphne	1	1,380 00
t-boats	3	931 50
ttress-boats	2	8,280 00
chine-shop boat	1	5,865 87
een boats	4	4,140 00
arter-boats	4	6,266 53
vey boat	1	779 41
ges	24	30,070 20
ffs	15	255 30
-drivers	9	28,613 67
l-shells	2	414 00
ls and appliances		5,000 00
ce furniture		150 00
veying instruments		150 00
Total value		96,947 08

H 1.

PORT OF ASSISTANT ENGINEER W. M. REES UPON OPERATIONS IN THE SECOND DISTRICT.

MEMPHIS, TENN., *June* 17, 1885.

CAPTAIN: I have the honor to submit my report upon the work of improving Mems Reach and Harbor from October 1, 1884, to June 30, 1885.

MEMPHIS HARBOR.

This work was in progress on October 1, 1884. At that time several unsuccessful empts had been made to sink mattresses 250 feet and 300 feet wide. These widths re deemed necessary in order to reach the greatest channel depth, which was from to 100 feet.

After the second mattress broke, whilst sinking, the plan was postponed until suite material for stronger construction could be obtained, and also until a more fav.ble condition of the river presented, as it was then rising with drift running. In mean time work on constructing mattresses 150 feet wide was begun and these were ced along the city front from Wolf River to below the foot of Jefferson street, and o extended above Wolf River for a distance of 1,230 feet and into Wolf River for istance of about 150 feet, forming a sill across its mouth. All these were sunk ring low water. They were well anchored to fastenings on the bank with wire cables

every 50 feet. The bank was then graded to an easy slope, and a revetment of double thickness of brush placed thereon; this was covered with stone in juxtaposition. Soft places on the bank and pockets near the water line were covered or filled with cypress bark. Care was taken to connect well the upper and lower revetments, and where they could not be wired together floating mattresses, continuous with the upper revetment, were built to overlap the lower work by at least 30 feet. This overlapping occurs for about three-fourths of the entire length of revetment, making at or near low-water line a double thickness. To prevent steamboats from displacing the brush of the upper revetment wire cables were placed alongside the transverse poles and wired to the grillage poles below. Preparation being completed, and the water being sufficiently low, work on mattresses 250 feet wide was resumed on November 4, the project being to place these on top of the 150-feet mattresses from Wolf River to Jefferson street. Work began as near below Wolf River as it was considered safe to place mooring barges, the lines from which could not be led across the river without interfering with the transfer steamboat.

Especially constructed mooring barges held the head of the mattress. The latter was strengthened by more and better constructed iron chains than used on previous mattresses, and also by weaving through and near its outer edge two 2-inch manila lines and one 1¼-inch line; these were sunk with the mattress. In sinking one of these 600-feet long mattresses I used sixteen ropes at the head and three ropes leading diagonally across and fastened at different points to the mattress. Nearly all ropes were of 2-inch diameter. The outer two at the head were of 2¼-inch diameter. In all, three mattresses were sunk, extending from 400 feet below Wolf River to the middle of the Memphis Elevator, a total length of 1,567 feet. More would have been placed had not the rising water rendered it unsafe to proceed.

To protect the work from the effect of sipe water a number of drains were built; one was a plank box 12 inches by 18 inches inside, draining the waters that collect under the Memphis Compress Company's shed into Wolf River; its length is about 1,000 feet. Others were placed along the bank, made either of plank or of stone, placed upon a foundation of cypress bark.

Incidental to preparing the bank for revetment, foundation walls and piling were removed and the wreck of a large model barge blown up with dynamite.

A cave on the paved levee at foot of Jefferson street took place during the high water of 1884; this was repaired by the city authorities during the summer, but it again caved out during November. The paving ended against a row of piling along which scouring was taking place, due to the eddy from the sunken barge above. This was repaired the second time by sinking three or four mattresses 24 feet wide on top of each other and against the piling, using a liberal quantity of stone, thus forming a revetment wall to support the levee. The slope of bank outside was nearly flat.

The total length of bank revetment is 4,680 feet. The entire work has stood the test of this year's high water very successfully, showing no signs of weakness although the current in front of it is as strong as before, when caving was taking place.

HOPEFIELD BEND.

The project here was to replace the revetment washed out during the high water of 1884 and to repair breaks and weak places in the work above.

The new revetment work extended 3,300 feet. It was constructed by first driving a row of piling a few feet out from low water, against this a mattress 150 feet wide was built and well secured to the piles before being sunk. The upper revetment extends from the top of the bank to 24 feet beyond the piling around which it is built. When sunk, this laps the lower revetment by 24 feet with a pile passing through each every 8 or 9 feet. The construction was the same as in Memphis Harbor The work was completed during November, when the entire force of over 200 men began repairing the upper bank caves of last year, and placing protection work upon places where it had then been omitted or was of insufficient strength. This was continued until the closing of the work by high water and running ice, and was then in an unfinished condition.

In addition a mattress 686 feet by 150 feet was placed across Mound City chute to replace work washed out by the cave of December, 1883.

A large amount of work was done in repairing former work, as nearly all upper revetment had been made of insufficient strength and the connection with the lower work was very inferior. The upper bank caved: (1) Through want of proper protection, the work not being covered to the top, but ending against a hard stratum, which, however, slowly washed, allowing the water to get behind the revetment. (2) Through inferior construction of upper revetment, particularly where joined to lower mattress, causing breakage upon slight settling of bank or mattress, and exposing a portion of the bank to the river. (3) Through settling of entire revetment towards the deep water, caused by the revetment not reaching to the deep channel, thus allowing it to be undermined. (4) Sipe water softening the material under the revetment usually near the low-water line. A large portion of the revetted bank is composed mostly of sand.

Before closing work the bank below was cleared of timber to facilitate the caving of Hopefield Point and thereby relieve the pressure against the Memphis front. The width of clearing was 200 feet back, just below the work, and 600 feet at the end of the timber about 3,000 feet below. During this year's high water all this clearing has caved in, the caving continuing to Hopefield Point, where it is about 525 feet. Here the Memphis and Little Rock Railroad Company were compelled to move their transfer incline not less than five times.

No serious caving has taken place along the revetted bank, and it is thought that the lower revetment is unbroken. The upper revetment shows breaks in a number of places, the most noticeable being about the middle of the work, where no sign of the mattress work was seen at the 12-foot stage, although here it had been carried to the top of the bank. The bank settled in a series of vertical prisms behind the work, gradually lowering out of sight. Whether the lower revetment is still in place I cannot say, although from the small extent of the caving back, the presence of the work immediately above and below, and the strong current in front, I judge it is unbroken, but has settled towards deep water.

Some slight recession has taken place just below the head of the timber, where the upper bank is of hard material, and where no work was placed last season. The lowest stage of water (12 feet) showed that about 300 feet of the lower end had caved off. With a deep eddy immediately below, and also that the upper edge of the new work had settled in four places, the largest being about 15 feet down by 300 feet across. Whether this settling is due to sipe water or to the moving down of the lower revetment it is impossible now to determine.

No caving has taken place above Mound City Chute, where it caved considerably during the high water of 1883 and 1884.

Caving has taken place on the head of Old Hen Island and on the Tennessee shore just above the steamboat channel across Owen's Bar, being nearer the Tennessee shore and fully 3,000 feet lower than last year.

Towards the close of the work the supply of stone ran out, and I had to resort to ballasting with sacks filled with gravel, a good quality of which was obtained near the work; 33,900 sacks were used, the average weight being 185 pounds each.

SURVEYS.

A survey party was employed until February 4, 1885. They made a triangulation survey from Island No. 40 to President Island, establishing range stations, and sounding over them at regular intervals, but as no soundings have been taken since high water no comparison as to changes can be made.

PLANT.

No new boats or barges have been added and none lost from service. All the floating property is in fair serviceable condition. Pumps for hydraulic grading were placed on a pile-driver hull in November, 1884. They discharged about 450 gallons per minute at a pump pressure of 225 pounds per inch, grading during ten days of work an average of nearly 200 cubic yards of earth per hour, at a cost of 2 cents per cubic yard. Two graders were employed.

Statement of work done.

MEMPHIS HARBOR.

Mattress made, 1,770 feet by 150 feet	squares		2,655
Mattress sunk, 2,071 feet by 150 feet	do		3,107
Mattress made, 1,567 feet by 250 feet	do		3,918
Mattress sunk, 1,567 feet by 250 feet	do		3,918
Upper bank revetment, completed	do		5,912
Earth removed, hydraulic grading	cubic yards	17,481	
Earth removed, hand grading	do	5,963	
			23,444
Cypress bark placed on bank	cords		1,850
Box drains built	feet		1,200
Material used:			
Brush	cords		11,978
Poles	do		440
Stone	cubic yards		13,654
Lumber	feet, B. M		21,823
Bark	cords		1,850
Wire	pounds		95,142
Wire rope	do		14,733
Iron rods	do		85,867
Spikes	do		22,500

HOPEFIELD BEND.

Mattress made, 2,815 feet by 150 feet	squares..		4,243
Mattress sunk, 2,978 feet by 150 feet	do....		4,467
Upper bank revetment, completed	do....		6,536
Earth removed, hydraulic grading	cubic yards........		63,251
Earth removed, hand grading	do....	9,861	
			73,112
Banks cleared of timber	acres..		26
Gravel loaded in sacks	cubic yards..		3,135
Material used:			
Brush	cords..		14,674
Poles	do....		282
Stone	cubic yards..		6,487
Wire	pounds..		98,090
Spikes	do....		17,800
Gravel	cubic yards..		3,135

COST OF WORK.

Memphis Harbor:		
Mattressing	$60,867 23	
Grading	3,581 62	
Hauling bark	1,408 50	
Building drains	405 65	
		$66,263 10
Hopefield Bend:		
Mattressing	55,138 82	
Grading	5,599 74	
Clearing bank	366 20	
Loading gravel	1,238 34	
		62,343 10
General work:		
General administration and care of fleet	10,212 47	
Surveys	1,928 63	
Steamers	7,018 56	
Construction of plant	2,359 34	
Repairs to plant	7,389 12	
Transferring rock	3,583 90	
		32,492 02
		161,098 22

Respectfully submitted.

W. M. REES,
Assistant Engineer.

Capt. SMITH S. LEACH,
Corps of Engineers.

APPENDIX I.

REPORT OF CAPTAIN C. B. SEARS, CORPS OF ENGINEERS, UPON OPERATION IN THE THIRD DISTRICT.

I.—LAKE PROVIDENCE REACH.

For an account of the extent of this reach, its physical characteristics, and the general project for its improvement, reference is made to the commissioner's report for 1883. All work done during the nine months past has been in conformity with the general project therein set forth.

The greater portion of the work has been bank revetment, to secure Louisiana Bend, Pilcher's Point, and prevent thereby a radical change in the regimen of the river immediately below, accompanied by a possible destruction of the contraction works there situated and a serious impairment of the good low-water channel which has resulted from these works.

The contraction work has been confined to repairs in former work, the construction of three cross dikes in chutes, and the building up to a higher level of the wattling on the main dikes.

The contraction work was brought to a close January 2, and the revetment work January 31, 1885, and the working forces discharged.

A survey party was maintained until March, 1885, engaged in slope and discharged observations and quarterly and special surveys.

Congress having adjourned March 4 without making any appropriation, the survey party was discharged and the force in charge of public property reduced to one assistant engineer at a reduced salary and a small number of boatmen and laborers just sufficient for the care of the fleet. This latter was assembled at Wilson's Point and put in good shape for care and preservation. It consists of two hundred and eleven pieces.

(1) *Duncansby to Stack Island.*

Assistant Engineer Arthur Hider, in immediate local charge, assisted by Assistant Engineer Childs, in charge mattress and revetment work; Assistant Engineers Ruple and Tollinger in charge of dike work; Assistant Engineer Thompson in charge of surveys and observation.

DUNCANSBY SYSTEM.

No further work has been done here. The main channel has continued its encroachment on the dikes at the head of the Duncansby Chute, and has carried away everything above cross dike No. 8 except a few hundred feet of No. 7. This cross-dike (No. 8) and the main dike below are all that remain of the Duncansby system.

The dikes that have been cut away by the main channel encroaching bodily had practically accomplished the object of their construction, viz: The closing of the head of Duncansby Chute and the consequent elimination of the danger of the main channel shifting into this chute. The angle of direction of the axis of this channel is now so obtuse with reference to the axis of the chute as to obviate this danger.

MAYERSVILLE SYSTEM.

Cottonwood dikes.—These dikes were finished at date of last annual report. No repair work has been done and but little needed. At present date the water has not fallen sufficiently to determine by inspection the amount of fill behind these dikes caused by the winter and spring rises. It will not be very great, as the rises have not been high, 35.13 feet on Lake Providence gauge, 3 feet lower than high water, 1884. The water was charged with comparatively little sediment.

Mayersville Chute.—An additional cross-dike (No. 3) has been built in the chute about 500 feet above Range 55. It is 450 feet long. One hundred and twenty linear feet of double dike, to strengthen No. 1, has been built.

The channel has continued its encroachment on the dikes at the head of the chute. The small portion remaining October 1, 1884, has all been carried away, together with some 750 feet off the head of the island. Here, as at Duncansby, the direction of the main channel has become so oblique to the chute as to allay any fears of its going down this chute.

REVETMENT OF MAYERSVILLE ISLAND.

Further repairs to the revetment work at the head of the island, covering some 700 linear feet of bank, were made in October, but, as foreshadowed in my last report, this has all been carried away by the direct impingement of the main channel. The island is made up entirely of fine sand, and the current at the head and along the river front is very strong. The whole head and front have been revetted twice, and a portion of the head three times, that is to say, the original length of the revetment was 8,930 linear feet, but work representing 15,578 linear feet has been done.

There is now standing but 54 per cent. of the original linear length.

BALESHED SYSTEM.

Two cross dikes in the Baleshed Chute, continuation of Nos. 8 and 11, 506 and 667 linear feet, respectively, have been built, and the wattling on the main dike raised several feet. The low water at time of construction, and want of funds after the water rose, prevented the entire completion of these two cross-dikes, and the refilling of the gap in the diagonal dike at the head of Stack Island, made for the passage of plant.

During the last high water in January a gap was made in the main dike between cross-dikes Nos. 8 and 9. This was the oldest part of the dike; the piles were very rotten, and were probably broken off by drift. This gap is now about 1,000 feet wide, and on June 4 had 15 feet of water through it in deepest part; Lake Providence

gauge, 23.5 feet. This gap should receive early attention, as soon as funds are available, as the direction of the current is acute with reference to the main channel, and the river may take its course down back of Stack Island.

The place in main dike between cross-dikes 5 and 6, that gave so much trouble last fall, and which was repaired the last of the season, has stood well, and is in a fair way to fill up and permanently strengthen itself.

For further details of the work see report of Assistant Engineer Hider herewith.

(2) *Louisiana Bend, Pilcher's Point.*

Assistant Engineer J. E. Turtle in charge, assisted by Assistant Engineers Steubling and Armstrong.

This is entirely revetment work, and consists (1) of a mattress built on the water and sunk so as to bring its inner edge at low-water mark, the width of the mattress extending along down the under-water slope; this is the lower-bank protection; (2) of a mattress, well ballasted with riprap, built in situ on the bank from low to high water mark, after the bank has been graded to a uniform slope of from 1 to 2 to 1 to 4; this is the upper-bank protection, and (3) of a lapping foot-mat attached to the upper mattress and extending out, so as when sunk to lap well over the lower mat, thus covering and strengthening the connection between the two.

At the date of last report the lower bank had been revetted from Range 17 to Range 21¼, a distance of 10,000 feet. The upper bank had been graded and revetted from Range 17 to Range 18.7, a distance of 3,600 feet, and the upper bank graded, but not revetted to a further distance of 1,450 feet. Since then the low-water revetment has been continued to Range 22.4, a further distance of 2,500 feet; the upper bank has been graded and revetted a further distance of 7,850 feet down to Range 21.9, and graded, but not revetted, a further distance of 1,050 feet, or down to Range 22.4; a foot-mat connecting and strengthening the upper and lower bank revetment has been constructed from Range 17 to Range 22.4, a distance of 12,500 feet.

Work stopped on January 31, for want of funds. At this date the bend was well revetted from Range 17 to 22.4. The work had been thoroughly well done and there was every prospect that the bank would hold. The lower mattress extended well out on the lower slope, in a number of places opposite pockets being over 300 feet wide. No accidents occurred to any mattress in sinking, and all went down in good shape. The upper bank was well graded before revetting, and the brush revetment was well and heavily ballasted before the water began to rise.

Soon after work stopped, about February 5, breaks began to take place at irregular intervals, and continued up to April 20. These were in length from 50 to 400 feet, and extended back from 0 to 125 feet. As yet the water has not been low enough to examine the lower part of the revetment. No local causes for these breaks can be determined. In some places the upper bank revetment seems to have slipped down, leaving the bank vertical but without further caving, while in other places the caving has extended back some 125 feet, and the upper mattress has either flattened out on to the bottom, or, revolving on its lower edge where attached to the lower mattress, has tipped forward and dumped its ballast and remains floating on the water.

A survey made in March, 1885, and compared with that of November, 1884, showed that there has been no general deepening of the channel, but the deep water has shifted over towards the concave shore, and the lower mattress has sunk down and flattened out, dragging the upper mattress with it in places. This accounts for there being as yet no falling back of the general line of the bend where it has been revetted. The part below the revetment, *i. e.* down-stream, has caved back from 200 to 600 feet, clear down to the point on Range 26.

During the last high water the current in the bend was exceedingly strong and turbulent, with many boils and eddies. The bank above the head of the revetment, which for years had resisted the action of the current, gave way suddenly during the last high water and caved back so rapidly that a planter had not time to move away a lot of baled cotton placed on the bank for shipment.

Of the original 12,500 feet of revetment, there is now left only 70 per cent., or 8,750 linear feet, showing a loss of 3,750 feet. Had we had the money and means to begin repairs as soon as each break first developed, we doubtless could have reduced the percentage of loss very materially. I apprehend no further caving until next high water, when I should not be surprised to see the rest of the revetment go.

I confess my deep disappointment at the result of this work. It seems to me to demonstrate that the average bank of the Lower Mississippi cannot be held at a reasonable cost by this form of revetment. Had the bank been revetted with double lower mattress as was done along the Memphis City front, I think it would have held, but the cost would have been about double what it was, or about $30 a linear foot.

FINANCIAL STATEMENT.

Improving Mississippi River, October 1, 1884, *to June* 30, 1885.

Balance available October 1, 1884		$263,492 67
Refunded on account of an overpayment		10
Transferred from the general service		56,000 00
Received from sale of fuel to officers		31 50
Transferred from Vicksburg, Harbor allotment		2,000 00
Transferred from levees, Tensas front allotment		7,700 00
Transferred from levees, Yazoo front allotment		2,000 00
Transferred from survey, Choctaw Bend allotment		1,320 14
Total		332,544 41
Expended from October 1, 1884, to June 30, 1885:		
Services	$131,209 66	
Material and supplies	86,485 29	
Subsistence	29,546 65	
Plant, tools, and repairs of same	46,434 61	
Charter of steamers and barges	3,130 00	
Fuel	8,881 51	
Miscellaneous	4,786 24	
		310,473 96
Balance June 30, 1885		22,070 45

Of this balance $3,880.67 is pledged to meet unpaid liabilities.

(3) SUMMARY.

The original condition of the channel-way along the Lake Providence Reach was bad, the channel being flat, badly defined, and often in extreme low water, with only 5 feet depth.

The original project for improvement was the narrowing of the water-way to 3,000 feet by closing the chutes and creating artificial banks through deposition and the preservation of the natural curves of the river by revetting the caving banks. No important changes have been made in the general plan.

The total amount expended to October 1, 1884, was $1,863,653.15.

At that date the availability of the channel for the purpose of navigation and commerce had been greatly improved, there being throughout the reach a depth of not less than 15 feet with a fair navigable width and regular course.

During the nine months ending June 30, 1885, there have been expended $310,473.96. The channel has continued to improve.

November 29, 1884, Lake Providence gauge, 6.58 feet.

Stack Island crossing had 19 feet against 17 feet September 19, 1884, gauge 6.6 feet; and Ben Lomond crossing had 16 feet November 29, against 15 feet; September 19.

There are indications that the channel opposite Shipland may divide in low water and go down on both sides of Ajax Bar. If this occurs the crossing here will probably be the shoalest on the reach. It may be necessary, when work is resumed, to close one of these channels.

I am not prepared to ask for any definite sum as being the amount that can profitably be spent during the next fiscal year, as this will depend upon whether we continue the experiments of revetting caving banks.

For the repairs of dikes in the Mayersville and Baleshed systems, the repairs of plant, care of property, &c., and dike work at Ajax Bar, if it prove necessary, $200,000 can be profitably expended.

If revetment work be renewed, $400,000 in addition can be expended during the fiscal year ending June 30, 1886.

The advantages and benefits to be expected from the repair of the dikes will be the maintenance of the present good low-water channel.

An estimate for the entire and permanent completion of the work of improvement on this reach I am unable to give, not knowing the intentions of the commission as to the ultimate extent of the work. As this work is only one link in the chain of general improvement of the river, the amount of commerce and navigation that will be benefited is that incident to the whole river.

The present estimated value of the plant, tools, and outfit on hand belonging to the reach is $340,000.

II.—VICKSBURG HARBOR.

Assistant Engineer H. St. L. Coppée, in charge.

The work here consists of the improvement of the harbor proper (Centennial Lake, in front of the town) and the maintenance of Delta Point, Louisiana, opposite Vicks-

burg. The former is entirely local in character, and would add nothing to the general improvement of the river. No funds were allotted from the last two appropriations, and no work has been done.

DELTA POINT, LOUISIANA.

The holding of this point is deemed essential to prevent further recession of the river from Vicksburg and to maintain the regimen of the river immediately below. This has been held by a mattress and riprap revetment for nearly three years, but at considerable expense for repairs and enlargement.

The work on the down-stream prolongation of the revetment was finished October 10, 1884. In March two slides took place in the upper bank revetment, just below a large eddy, about the middle of a length of the revetment. They aggregate about 400 feet in length along the water line. The sliding then stopped, and was accompanied by no material caving. Funds having been assigned, I ordered plant and material sent down from Lake Providence Reach, and these breaks were repaired, taking about six weeks and costing some $9,400. No further damage has taken place, and none is apprehended until the next high water.

The Vicksburg and Shreveport Railroad has shown its faith in our ability to hold the point by ordering an incline to be built at Delta Point to be used for the transfer of trains in connection with an incline on the Mississippi side. The one on the Louisiana side will cross over our revetment, and its stability will depend upon that of the revetment.

The total expenditure on Vicksburg Harbor under the Commission to June 30, 1885, has been $166,792.25, and of this about $110,000 has been expended on Delta Point. Previous to the Commission taking charge $203,229.87 had been expended on Delta Point.

It would be well to have $20,000 available during the next fiscal year for repairs on this work should more weak places develop.

FINANCIAL STATEMENT.

Balance available October 1, 1884	$10,720 69	
Allotted November 1, 1884	4,000 00	
Transferred from general service allotment	10,000 00	
		$24,720 69
Expended from October 1, 1884, to June 30, 1885:		
Services	$8,469 93	
Material and supplies	6,164 69	
Subsistence	1,732 37	
Plant, tools, and returns	575 82	
Charter of steamers	714 00	
Fuel	811 50	
Miscellaneous	569 50	
	19,037 81	
Transferred to Lake Providence allotment	2,000 00	
		21,037 81
Balance June 30, 1885		3,682 88

Of this, $2,958.82 is pledged to meet unpaid liabilities.

LEVEES.

Yazoo front.—The $20,000 allotted for this front in the third district has been expended in repairs to United States levees from Riverton to Huges, and Clay and Bagott's to Easton, Miss.

Proposals were advertised October 8, 1884. Bids were opened October 20; contracts were made with the lowest bidders respectively on the two sections, viz: From Riverton to Huges, some 33,000 cubic yards, to W. C. P. Jones, at 22 cents a cubic yard for earth-work, 1 cent a square yard for tuft-sodding, and 2 cents a square yard for solid sodding; from Clay and Bagott's to Easton some 32,000 cubic yards, to L. C. Dulaney, at 23 cents a cubic yard for earth-work, 1 cent a square yard for tuft-sodding, and 9 cents a square yard, for solid sodding.

These contracts were fulfilled and the work finished on both sections in February, 1885.

Tensas front.—The work of filling gaps in the levee from Delta to Bedford, and Raleigh to Willow Point, La., 94,000 and 125,000 cubic yards, respectively, let to George

Arnold, and referred to in my last annual report, was begun in October, 1884, pushed forward energetically and satisfactorily finished in February, 1885. Proposals for the repair of the levee from Wilton to Raleigh, and Pecan Grove to Willow Point, La., some 15,000 cubic yards, and on the Buckhorn levee from Omega to Rose Hill, La., some 5,000 cubic yards, were advertised November 25, 1884; bids were opened December 5, 1884, and the contract awarded to Joseph C. Neely, at 26¼ cents a cubic yard. The work was all topping work, and was finished in March, 1885.

There not being sufficient funds to make earth-work repairs to the Illawara main front, rough lumber was bought and this front revetted with boards, end on and spiked to sills anchored in the old levee.

The necessary guarantees having been given, proposals for building the levee from Arkansas City to Amos Ridge, Ark., some 325,000 cubic yards, were advertised November 2, 1884, bids were opened November 8, 1884, and the contract awarded to the Tennessee Industrial Company, John D. Adams, president, at 24 cents a cubic yard, including clearing and sodding. The contractors guaranteed to build the whole line under my direction and to my satisfaction, and to receive for their work not to exceed $25,000, the amount allotted.

Work was begun in November and satisfactorily finished in April.

This, for the first time for years entirely closes this line and the head of Tensas interior basin. There are now but two gaps in the United States line below Arkansas River, viz, at Duffin's and Panther Forest.

FINANCIAL STATEMENT.

Levees—Yazoo Front.

Balance, October 1, 1884		$23,594.25
Expended:		
Services	$2,338 89	
Labor and material	245 66	
Contractors' estimate	18,488 72	
Miscellaneous	346 43	
	21,419 70	
Transferred to Lake Providence allotment	2,000 00	
		23,419 70
Balance available June 30, 1885		174.55

Levees—Tensas Front.

Balance, October 1, 1884		$57,186 47
Expended:		
Services	$3,563 19	
Labor and material	1,471 85	
Subsistence	8 50	
Plant, tools, &c	889 84	
Contractors' estimate	42,831 96	
Miscellaneous	688 87	
	49,454 21	
Transferred to Lake Providence allotment	7,700 00	
		57,154 21
Balance, June 30, 1885		32 26
Levee, Arkansas City to Amos Ridge, allotted		25,000 00
Expended for engineering, inspection, and contractors' estimate		25,000 00

Respectfully submitted.

CLINTON B. SEARS,
Captain, Engineers.

To Col. Q. A. GILLMORE,
Corps of Engineers, U. S. A.,
President Mississippi River Commission.

I 1.

REPORT OF ASSISTANT ENGINEER ARTHUR HIDER UPON OPERATIONS IN THE THIRD DISTRICT.

WILSON'S POINT, LA., *June* 8, 1885.

SIR: The following report of the operations of the Lake Providence construction party from October 1, 1884, to June 30, 1885, is respectfully submitted:

The construction work done since the last report has been confined to repairs to the revetment at the head of Mayersville Island, which had begun to cave; the construction of additional cross-dikes in Mayersville and Baleshed chutes and wattling the dikes that had heretofore been built on Baleshed Bar and Stack Island.

Extensive repairs became necessary to the revetment along the face of Mayersville Island as the season advanced, the sliding and caving increasing. These repairs were completed December 6, 1884, and the work to all appearances left in good condition to withstand the winter rise.

The cross-dike across Mayersville chute, 500 feet above range 55, was finished except sinking the foot-mat. Cross-dike No. 8 in Baleshed chute was finished complete, but No. 11 and the gap in Stack Island main dike were necessarily left in an unfinished condition by reason of the sudden suspension of work.

EFFECTS OF THE LAST HIGH WATER ON THE CONSTRUCTION-WORK DIKES.

Duncansby dikes.—The river channel has still further encroached on the bar at the upper end of the Duncansby chute, further scouring out the outer ends of the cross-dikes, as had been anticipated in the last report.

However, the river shows no disposition to go down the chute; the caving has entirely ceased, there is little current, and the dikes originally constructed at the head of this chute may be considered to have served the purpose for which they were designed, viz, to prevent the enlargement of the chute and overcome the tendency of the river to take this course.

Gaps about 50 feet wide have been washed out in Cross-dikes No. 7 and No. 8, near the Mississippi shore.

Cottonwood dikes.—This system of dikes has suffered but little damage; a few piles in the outer rows of the main dike have been broken off by drift. The bar behind these dikes has increased both in height and length.

Mayersville dikes.—The main cross-dike has remained intact. The drift accumulations in front have nearly doubled; a gap of 100 feet in width was washed out in Cross-dike No. 3. The foot-mat on this dike was built but not sunk.

Baleshed dikes.—A gap of about 300 feet in length occurred in January by the breaking off of the piles by drift in the main dike between Cross-dikes No. 8 and No. 9. This gap has increased to about 1,000 feet in length, beginning 400 below Cross-dike No. 8 and extending below Cross-dike No. 9, which has been washed out. At this stage (23.5 feet) there is a considerable volume of water passing through this break. The maximum depth at the upper end is 15 feet, whence it gradually shoals to the lower end of the break.

This water flows to the left of Stack Island, and the gap is so located as to aid the river in its efforts to again form a channel behind the island. It is unfortunate for the success of the work that there are no funds available to repair this break.

The gap left in dike No. 11, and which was not closed on account of the stoppage of the work, has increased from 50 to 150 feet in width, due to the break in the main dike, to which reference has been made above.

Stack Island dikes.—After the completion of the cross-dike, it became necessary to make an opening through this dike in order to get material to Dikes 8 and 11, which had been ordered constructed. The abrupt suspension of all construction work prevented its closure. This gap has increased from 75 to 150 feet in width, due to the breaks mentioned above.

REVETMENT WORK.

Mayersville Island.—The effect of the last rise upon the revetment at the head of Mayersville Island has been to undermine the work at the extreme upper end. This undermining continued, caving begun and increased as the river fell, until it now extends from the head of the island down to a point about 500 feet above Range 53 (a distance of 3,400 feet). Above this point all the revetment has washed out. Opposite to where the upper end of the island was, the caving has extended back 600 feet. The present head of the island is 700 feet further down-stream than it was at the close of the work last season.

About 46 per cent. of the revetment which was reported in fair condition October 1, 1884, has been destroyed. The caving will continue, unless arrested, as the main current of the river impinges directly upon the head of the island.

Pilcher's Point Revetment.—The revetment finished last season along Louisiana Bend caved in places during the high water. These caves have increased in size somewhat, and now aggregate about 30 per cent. of the entire work. No new breaks have occurred within the last two months, and in no place does the caving extend back more than 125 feet.

CHANGES IN THE CHANNEL.

Considerable caving has taken place on the right bank below the revetment work at Pilcher's Point, forcing the crossing lower down and inducing caving on the left bank where the current impinges between Range 30 and Range 34. The river again makes a crossing to the Louisiana side above the head of the Duncasby Dikes, and then deflects back again, striking the Mississippi shore between Wilderness Landing and the upper end of Mayersville Island, following along the face of the island it deflects back to the right bank at Longwood; thence along the Louisiana shore to Elton, where it again deflects to the left bank at Ben Lomond. From here the channel crosses to the Louisiana side at Stone's, following the shore to Wyley's, and again crosses back to the Mississippi shore at Shipland. At this point there are indications that the channel may divide, during low water, on each side of Ajax Bar, which, if such should be the case, would, in all probability, cause this crossing to be the shoalest on the reach. From here the channel follows the same course as last season to the head of Island 95. The channels for the approaching low-water season will be about the same as during the last low water, except, possibly, the change indicated at Ajax Bar.

During the low-water period of October, November, and December, soundings were taken on the two shallow crossings on the reach with the following results. These soundings were kept up during the high water of January and February, 1885:

Shallow crossings, Lake Providence Reach.

Date.	Lake Providence gauge-readings.	Least depth Stack Island crossing-channel, 1,000 feet wide.	Least depth Ben Lomond crossing-channel, 1,000 feet wide.
1884.	*Feet.*	*Feet.*	*Feet.*
October 10	14.8	24.5	15.0
October 20	13.7	26.0	24.0
October 30	12.0	24.5	22.5
November 10	11.1	23.0	26.0
November 20	7.25	21.0	17.0
November 29	6.58	19.0	16.0
December 9	7.83	20.0	18.0
December 19	11.00	22.5	19.0
December 30	12.00	21.0	20.0
1885.			
January 10	29.45	40.0	39.0
January 19	33.59	[illegible]	43.0
January 30	34.65	44.0	42.0
February 9	31.45	[illegible]	38.5
February 20	27.08	38.0	33.0
February 28	21.29	34.5	26.5

From the above it will be seen that improvement took place in channel depth in the latter part of 1884, when compared with the low water of August and September earlier in the season given below:

Shallow crossings, Lake Providence Reach.

Date.	Lake Providence gauge-readings.	Stack Island, 1,000 feet channel, least depth.	Ben Lomond, 1,000 feet channel, least depth.
1884.	*Feet.*	*Feet.*	*Feet.*
August 9	15.5	18	24
August 19	12.6	14	12
August 30	8.9	10	14
September 9	9.1	14	17
September 19	6.6	17	11
September 30	5.8	15	11

From all indications there seems to be no reason to anticipate any decrease of depth in these two crossings during the coming low-water season, which, for the last two seasons, have been the shallowest places on the reach.

SURVEYS.

The work of the survey party has been the completion of the low-water survey of October, 1884, special surveys to determine the effects of the construction works, discharge measurements, slope observations, and the preparation of progress sketches.

Below is a summary of discharge observations taken at Wilson's Point, from October 1, 1884, to March 5, 1885:

Date.	Lake Providence gauge.	Area.	Mean velocity per second.	Discharge per second.
1884.	*Feet.*	*Square feet.*	*Feet.*	*Cu. Feet.*
October 21	13.90	115,404	3.442	397,225
November 25	6.84	86,448	2.929	253,207
1885.				
January 3	21.05	121,547	4.018	488,334
January 8	27.93	155,310	5.186	805,382
January 13	30.75	169,065	5.779	977,038
January 21	33.93	174,417	5.272	919,578
January 29	34.61	178,151	5.304	960,923
February 6	33.70	181,883	5.119	931,161
February 14	28.28	156,660	4.393	688,226
February 19	27.15	150,568	4.379	698,681
February 25	24.65	149,472	4.106	613,789
March 5	17.51	125,572	3.546	445,281

The highest gauge reading (Lake Providence gauge) was May 10, 1885—35.10 feet; lowest, December 14, 1884—5.50 feet.

SUMMARY OF WORK DONE.

Field work:

Discharges obtained	number..	14
Discharges computed	do....	12
General slope taken	do....	1
Shore line located	miles..	65½
Gauges tested and reset	number..	55
Signals replaced	do....	297
Ranges sounded	do....	136
Leveling	miles..	52.2
Crossings sounded	number..	30
△ erected	do....	10
Special surveys	do....	15
Lines cleared	miles..	19

Office work:

Maps made	number..	58
Tracings	do....	61
Progress sketches	do....	5

Copies of these maps have been forwarded to you from time to time.

Assistant Engineer Ture Lowegren died on March 17, of swamp fever.

The party was disbanded on the 20th.

List of barges, pile-drivers, tow-boats, &c., constituting the floating property belonging to Lake Providence Reach.

Classification.	Number.	Dimensions.	Remarks.
		Feet.	
Tow-boats	4	....	Two with Missouri River Commission.
Graders	2	110 by 30	
Grader	1	80 by 16	Small.
	3		
Mattress-boat	4	160 by 30	
Do	2	200 by 30	
Do	1	149 by 49	Old.
	7		
Screen-boats	4	100 by 25	
Quarter boats	10	130 by 25	
Do	1	100 by 30	
Do	1	135 by 30	
Do	2	100 by 25	
Do	2	80 by 20	
Do	1	70 by 18	
	17		
Machine-shop boat	1	100 by 20	Old.
Do	1	211 by 35	New.
	2		
Carpenter-shop boat	1	211 by 25	
Dock	1	186 by 50	
Do	1	87 by 16	
Do	1	27 by 8	
	3		
Wharf-boat	1	100 by 24	
Derrick-boat	1	100 by 25	
Pump-boat	1	47 by 12	Steam.
Barges, decked	36	100 by 25	
Do	2	160 by 28	
Do	5	75 by 15	
Do	1	66 by 15	
Do	1	60 by 14	
	7		
Do	1	132 by 24	
Do	10	140 by 28	Do.
	56		
Pile-drivers	12	70 by 20	
Do	4	82 by 20	
	16		
Catamaran	1	....	
Calking flats	8	25 by 7	
Do	2	42 by 12	
	10		
Yawls	7	....	
Skiffs	59	....	
Coal-barges, open	4	120 by 26	Old.
Coal-barges, decked	12	120 by 26	Do.
Coal-boats	2	160 by 26	Do.
Total number pieces	211		

Below is given the amount expended for labor and subsistence:

Classification.	Pay-roll.	Subsistence.	Total.
Dike party	$7,154 19	$2,202 15	$9,356 34
Bank revetment party	4,716 82	1,527 47	6,244 29
Survey party	5,808 32	611 26	6,419 58
Tow-boats	11,455 31	1,863 91	13,319 22
Care of fleet	21,225 26	3,821 60	25,046 86
Rock party, Arkansas City	6,667 89	1,494 00	8,161 89
	57,027 79	11,520 39	68,548 18
Services of the United States steamer Vidalia at Delta Point, to be deducted from the above	196 63	49 00	245 63
			68,302 55

The maximum number of men employed in any one month was 467; the minimum, 45.

AVERAGE COST OF SUBSISTENCE.

Cost of raw material, each ration	$0.289
Cost of each ration served	0.379
Cost of each ration served for each day's labor secured	0.435

WORK DONE.

Grading	cubic yards	6,675
Wattling built, 16,168 linear feet	squares	2,880.5
Woven mat built, 2,190 linear feet	do	2,190
Woven mat, sunk, 2,190 linear feet	do	2,190
Grillage built, 1,467 linear feet	do	621
Grillage sunk, 1,467 linear feet	do	621
Revetment built, 1,750 linear feet	do	1,072.17
Revetment rocked, 1,835 linear feet	do	1,119.32
Dike driven	linear feet	1,743
Piles driven	number	655
Braces put on	do	425
Stringers put on	do	237
Rock loaded	cubic yards	17,826.1

MATERIAL EXPENDED.

Piles	number	658
Braces	do	425
Stringers	do	237
Poles	cords	215.9
Brush	do	4,270.8
Iron and spikes	pounds	28,561
Lumber	feet	47,675
Oakum	pounds	1,060
Stone	cubic yards	2,057.1
Coal	bushels	74,517
Wire	pounds	18,810

In compliance with instructions received on December 31, 1884, all construction work was suspended except the loading of stone by the force at Arkansas City for securing the unfinished revetment at Pilcher's Point, the men discharged, and the fleet laid up at Wilson's Point, only sufficient men being retained to care for the property. The force at Arkansas City was disbanded on January 20, 1885.

Very respectfully,

ARTHUR HIDER,
Assistant Engineer in charge.

Capt. CLINTON B. SEARS,
Corps of Engineers, U. S. A

APPENDIX K.

REPORT OF MAJOR AMOS STICKNEY, CORPS OF ENGINEERS, UPON OPERATIONS IN THE FOURTH DISTRICT.

UNITED STATES ENGINEER OFFICE,
New Orleans, La., June 17, 1885.

SIR: In compliance with your request I have the honor to submit the following report of operations in the Fourth District of the Mississippi River, to include the time from last annual report, October 1, 1884, to June 30, 1885. The works in this district are as follows, viz:

Construction and repair of levees.

Improvement of Mississippi River at Natchez and Vidalia, Miss. and La.

Improvement of mouth of Red River and rectification of the Red and Atchafalaya at mouth of Red River.

Improvement of the harbor at New Orleans, La.

Survey of Cubitt's Gap and vicinity.

LEVEES.

On the 27th of September, 1884, proposals were received for work on levees and the following were accepted:

Locality.	Names of bidders.	Number of yards.	Price per yard.
			Cents.
Point Pleasant Levee	James M. Searles	22,000	17½
Shipp's Bayou to Hard Times Levee	Dabney & Gray	38,000	25
Bondurant Levee	W. O. Flynn	35,000	17
Kempe Crevasse Levee	Hughes & McGinty	25,000	17
Lake Concordia Levee	Dabney & Gray	31,000	17¼
Hardscrabble Levee	Thomas O'Malley	75,000	24¾

Contracts were made as soon as possible, and by October 10 nearly all the parties were at work. Searles having failed to make contract under the conditions imposed, Hughes & McGinty, the next lowest bidder, took the work at 18¾ cents per yard. With the experience of past years to guide us, it was considered essential to make more rigid contracts and specifications in order that more perfect control of the work might be had, especially with regard to the number of men employed on each levee. With this in view each contract contained a clause specifying the number of men that should be engaged in the actual work of levee building, exclusive of the auxiliary force necessary for the work in camp, and in order to enforce this clause a provision was made by which men could be placed on the work at the contractor's expense. These new forms of contract and specifications proved to be most excellent in keeping the contractors up to the work In only one case was it necessary to put men on at the contractor's expense, and that only for a few days. At Kempe Levee work was continued and finished by hired labor. Late in the season, December 19, 1884, an allotment of $8,710 was made by the Commission for completing Evergreen Levee. This work was commenced by the authorities of Tensas Parish, but proved to be too extensive for the means at their disposal. A contract was made with Dabney & Gray, at 22½ cents per yard, for doing this work, which they completed March 2. All of the levee work which was undertaken this year was completed in good season, with the exception of a portion of the levee at Hard Times, which continued to sink as it was built up, and is only just finished. A short stretch of the Kempe Levee has also sunk so as to be in a dangerous condition in case of a high flood. Exhaustion of funds prevents any work being done at present, and there is no likelihood of danger until next spring, before which time funds may be available for placing the bank in good condition. Considerable repair work has been done on the levee built by the Government below Red River.

This work being scattered over a considerable line, and consisting mostly of strengthening weak places and general patching, was done by hired labor, it being difficult to specify it and get reasonable bids from contractors.

In connection with the building of Kempe Levee, a survey was made to determine the practicability of constructing another line in front of the lakes in case the present levee should cave into the river, and for the purpose of estimating the cost of protecting the banks. This bend is rapidly deepening by the caving of the bank.

During the year about 9 miles of levee have been built, closing forty gaps, and requiring something over 300,000 yards of embankment. The line of levees in the Fourth District is now in pretty fair condition, with the exception of a deficiency in height. The only gaps are:

	Feet.
Diamond Bend to New Carthage	50,000
Bougere Crevasse	23,400
Black Hawk to Red River	90,000
Morganza	6,000

On January 4, 1885, the store-house at Hardscrabble Levee, containing the tools and outfit used on that levee, was destroyed by fire with a considerable quantity of the contents. The caving bank at Kempe Levee threatened to fall into the river with the property stored at that point. Authority was, therefore, asked and received to construct a store-house on the high ground in Giles Bend just above Natchez, which was under rental in connection with the improvement in that vicinity. The storehouse was constructed, and all property pertaining to the levees carefully stored under the charge of watchmen, who also have the care of the Red River and Natchez property. For details of levee work reference is made to the report of Assistant Engineer H. S. Douglas, appended.

SURVEY OF KEMPE BEND.

The survey of Kempe Bend, in Tensas Parish, Louisiana, called for by the resolution of the Commission of May 12, 1884, was completed during the fall and winter The object of this survey was to ascertain approximately a line upon which a new levee could be built and the cost of protecting the caving bank, and was instigated by a petition from the police jury of Tensas Parish, who were alarmed at the rapid caving of the river bank and the possibility that a new line of levee would soon be required, and that it would not be practicable to construct a new line without falling back of Lake Saint Peter. The survey shows that a line can be constructed in front of the lake, with a fair location. A comparison of the line of the river bank with the lines of other years back to 1866, shows a very serious caving, about 5,500 feet, and increasing in rapidity. A little study of the map presents some startling figures. Here in one short reach of the river less than 6 miles in length 76,000,000 square feet of earth, with an average depth of, say, 100 feet, making 7,600,000,000 cubic feet of earth, have been moved by the river in nineteen years; an average of 400,000,000 cubic feet per year. The prevention of this caving, by works of bank protection, would permit a vast amount of energy to be applied to the maintenance and deepening of the channel, and an ultimate lowering of the water surface, which would, in my opinion, if extensively carried out in connection with works for contracting the channel at a few points, solve all the questions of improvement of navigation and prevention of overflow, rendering levees almost unnecessary above the mouth of Red River, in a comparatively short space of time. An inspection of the above figures should convince the most skeptical that bank protection is the great necessity in the work of improving the river.

The cost of protecting the bank in this bend with a system of submerged spurs is computed at $250,000. There are 25,000 feet requiring protection, and it is estimated that spurs at a cost of $10,000 each, placed at intervals averaging 1,000 feet in length, will be sufficient for the purpose. If the mattress system is adopted, the cost, at $18 per foot, would be $450,000. The cost of a new levee around Kempe Bend is estimated at about $199,500, and at present rate of caving would have to be built in about two or three years, some of it sooner. As the protection of the bank at this point would not only save the cost of the new levee, but also be a part and parcel of the work of river improvement, I would strongly recommend that the work be commenced as soon as practicable.

The report of Assistant Engineer H. S. Douglas on the survey is appended.

IMPROVEMENT OF MISSISSIPPI RIVER AT NATCHEZ AND VIDALIA.

No work has been done in this vicinity, owing to the lack of funds. The method of improvement recommended in previous reports to the Commission contemplates the protection of the caving banks by means of submerged sloping spurs placed at intervals to be determined as the work progresses, but assumed for estimate of cost at 1,000 feet.

The estimate of cost is $600,000.

To prevent the flow of flood water across the neck of land between Giles and Cowpen bends, it is proposed to construct a levee at an estimated cost of $100,000.

This makes the total estimate $700,000. If it became necessary to protect the caving banks by mattress work the cost for this item would approximate $1,040,000.

IMPROVEMENT OF MOUTH OF RED RIVER AND RECTIFICATION OF THE RED AND ATCHAFALAYA AT MOUTH OF RED RIVER.

At date of last annual report, October 1, 1884, the plant was at work in Old River keeping a navigable channel between the Mississippi and the Atchafalaya.

On October 1, the Mississippi reached its lowest stage at Red River Landing, being 6.3 feet on the gauge, and on October 3, began to rise. The channel was constantly maintained by hard work and various devices. The scouring by the use of the propellers of tugs lashed to a steamboat was not successful, except at a point near the Atchafalaya where a comparatively short bar existed, with deep water just beyond it. It became necessary to construct temporary spur-dikes of willow brush along one reach, and to drag a scraper hanging from the bow of a stern-wheel steamer at other places. The temporary spurs, I believe, offer the best method of keeping the channel open during a season at the least cost, if placed in time to take advantage of the current. They should be assisted by a stern-wheel steamer with a scraper. On October 8 operations were suspended, and on the 10th the tugs were passed through Old River with considerable difficulty, the surface slope of the water being 7.5 feet in 6 miles. The water did not reach as low a stage at Barber's Landing as it did in the previous year, and there was less sloughing of the banks. The channel remained in good condition till about November 27, when the Mississippi had again fallen to 7.65 at Red River Landing. Being apprehensive of further trouble I dispatched the steamer Annie Kelley, belonging to the New Orleans Harbor work, to resume operations with the drag scraper. She worked from November 30, to December 8, when the rising river made it unnecessary to continue longer.

No work has yet been done in this vicinity for a permanent amelioration of the difficulties of navigation which recur almost annually, and to prevent a further enlargement of the Atchafalaya.

The estimates of cost of the work proposed by me in my report of December 15, 1883, which were published in the last annual report of the Commission, were so distorted by mistakes in making extracts and by printers' errors, that I consider it proper to restate them here, as follows, viz:

Atchafalaya River work	$576,150
Upper Old River work	438,130
Lower Old River work	48,000
	1,062,280
Add 10 per cent. for contingencies	106,228
Total	1,168,508
For temporary work in Lower Old River to keep a channel while permanent work is progressing, and part of which would be utilized in the above item for Lower Old River	75,100
Add 10 per cent. for contingencies	7,510
	82,610
The entire cost would then be	1,251,118

And not $2,151,660 as it appeared in the report of the Commission.

A plan for the work in this vicinity was prepared by the Commission and published in their last annual report, but no instructions in reference thereto have been received by me.

For details of the work performed at the mouth of Red River, reference is made to the report of Assistant Engineer A. O. Wilson, appended.

PLAQUEMINE ROUTE.

The estimates for opening a navigation route to the Atchafalaya and Red rivers by way of Bayou Plaquemine having been presented to the Commission December 17, 1883, the maps were worked upon only at such times as assistants could be spared from other more pressing work, the assistant in charge of the survey having died in the field. Copies of the maps were forwarded to the secretary of the Commission March 2, 1885.

There is no question of the feasibility of establishing this route as marked on the map. The location and drawings of locks, and location of excavation work, as presented on the maps, were made for the purpose of estimating cost only. The inauguration of any work would, of course, necessitate further study and probable changes.

The report of Assistant Engineer A. O. Wilson, relating to the maps, plans, &c., is appended.

IMPROVEMENT OF HARBOR AT NEW ORLEANS, LOUISIANA.

At the date of last annual report, October 1, 1884, work was in progress in that part of the harbor designated as Gouldsboro' Bend. The construction of the first submerged spur had been commenced. The work continued until November 28, when it became necessary to suspend operations on account of the exhaustion of funds. Two spurs were completed and one spur about half built. Nearly all the stone for ballast, iron rods for mattress and crib work, and other material, except brush, are on hand for the completion of the six spurs which are to form the protection for this bend. It was originally intended to build the spurs so as to project horizontally 50 feet out into the river at low-water surface, but the new survey of the bend developed the fact that so constructed the spurs would be higher than was considered advisable in the experimental beginning of the work; the slope of the spurs was therefore started immediately from the low-water shore-line. They can be carried out into the river hereafter if it should be deemed advisable.

The effect of this work cannot be noted until the falling of the river diminishes the current sufficiently to permit accurate soundings to be taken in depths of 100 feet. The direction and velocity of the current have been favorably affected by the spurs, and, as far as can be noted, the structures have suffered no damage. The cost of this work has been about $12,500 for each spur as completed. This can and will be very considerably reduced in future work, as perhaps as much as one-quarter of the cost has been for experience in learning how to construct and sink the mattresses and cribs exactly in place in depths which at some points reach over 100 feet. The revised estimated additional amount needed for completion of work in New Orleans Harbor is as follows:

Carrollton Bend (mattress project)	$158,600
Gouldsboro' Bend (completion)	35,000
Gretna Bend	64,200
Bend above Gretna to a point nearly opposite the city park, right bank	396,600
Total	654,400

For details of the work reference is made to the report of Assistant Engineer W. G. Price, appended, and plates.

SURVEY OF CUBITT'S GAP AND VICINITY.

The survey of Cubitt's Gap, for which an allotment was made, was attempted in January, 1883. Owing to the dense and continuous fogs, the party accomplished scarcely any work, and was withdrawn to await a better opportunity. The cost of the party consumed nearly half of the allotment and application was made for an additional sum. This not having been granted as yet, the survey cannot be resumed.

A survey of the Mississippi River in the vicinity of the gap was made by the party stationed at South Pass under the direction and by the kindness of Maj. W. H. Heuer, Corps of Engineers, U. S. A., a platting of which will be incorporated in the map of the survey.

Very respectfully, your obedient servant,

AMOS STICKNEY,
Major of Engineers, U. S. A.

Col. Q. A. GILLMORE,
Corps of Engineers, U. S. A., President Mississippi River Commission.

Construction and repair of levees, Fourth District. Improving Mississippi River, no limit.

ATCHAFALAYA FRONT.

Act of Congress, passed August 2, 1882, for improving Mississippi River, no limit:

November 23, 1882, allotted	$110,000 00
Expended to June 30, 1883	97,525 42
Balance on hand July 1, 1883	12,474 58
Expended to June 30, 1884	12,474 58

Act of Congress approved January 19, 1884, for improving Mississippi River, no limit:		
March 25, 1884, allotted		$5,000 00
Expended to June 30, 1884		5,000 00
March 28, 1884, allotted		4,000 00
Expended to June 30, 1884		4,000 00
April 1, 1884, allotted		15,000 00
Expended to June 30, 1884		4,602 73
Balance on hand July 1, 1884		10,397 27
Expended to June 30, 1885		9,901 20
Balance on hand July 1, 1885		496 07
April 12, 1884, allotted	$12,000 00	
March 3, 1885, transfer to Tensas front	3,000 00	
Expended to June 30, 1885	0 00	
Balance on hand July 1, 1885		9,000 00
Total balance on hand July 1, 1885		9,496 07

TENSAS FRONT.

Act of Congress passed August 2, 1882, for improving Mississippi River, no limit:	
November 23, 1882, allotted	$426,160 00
Expended to June 30, 1883	228,520 31
Balance on hand July 1, 1883	197,639 69
Expended to June 30, 1884	197,637 94
Balance on hand July 1, 1884	1 75
Expended to June 30, 1885	1 75
Act of Congress approved January 19, 1884, for improving Mississippi River, no limit:	
February 27, 1884, allotted	5,000 00
Expended to June 30, 1884	5,000 00
March 24, 1884, allotted	10,000 00
Expended to June 30, 1884	10,000 00
March 28, 1884, allotted	6,000 00
Expended to June 30, 1884	141 12
Balance on hand July 1, 1884	5,858 88
Expended to June 30, 1885	5,858 88
Act of Congress approved July 5, 1884, for improving Mississippi River, no limit:	
August 5, 1884, allotment	90,000 00
Expended to June 30, 1885	89,388 24
Balance on hand July 1, 1885	611 76
December 19, 1884, allotted	8,710 00
Expended to June 30, 1885	8,710 00
March 3, 1885, allotted transfer from Atchafalaya front	3,000 00
Expended to June 30, 1885	3,000 00
Total balance on hand July 1, 1885	611 76

SURVEY UNLEVEED FRONTS, FOURTH DISTRICT.

November 20, 1882, allotment from appropriation for improving Mississippi River, no limit; for survey unleveed fronts, Fourth District:	
Act passed August 2, 1882	$1,000 00
Expended to June 30, 1884	902 12
Balance on hand July 1, 1884	
Expended to June 30, 1885	

IMPROVING MISSISSIPPI RIVER AT NATCHEZ AND VIDALIA, MISSISSIPPI AND LOUISIANA.

Aggregate expenditures on work before it was placed under the Commission		$81,747 96
Balance on hand July 1, 1882		8,252 04
Disbursements since work was placed under the Commission:		
Expended to June 30, 1883		2,343 37
Balance on hand July 1, 1883		5,908 67
Expended to June 30, 1884		1,847 25
Balance on hand July 1, 1884		4,061 42
Expended to June 30, 1885		2,435 47
Balance on hand July 1, 1885		1,625 95

MOUTH OF RED RIVER, LA.

IMPROVING MOUTH OF RED RIVER, LOUISIANA.

Aggregate expenditures on work before it was placed under the Commission		$99,187 60
Balance on hand July 1, 1882		90,812 40
Disbursements since work was placed under the Commission:		
Expended to June 30, 1883		37,663 73
Balance on hand July 1, 1883		53,148 67
Expended to June 30, 1884		34,844 98
Balance on hand July 1, 1884		18,303 69
Expended to June 30, 1885		18,303 69

MOUTH OF RED RIVER, LA.

IMPROVING MISSISSIPPI RIVER, NO LIMIT.

August 5, 1884, allotment from appropriation for improving Mississippi River, no limit, for improving mouth of Red River, Louisiana:		
Act approved July 5, 1884		$12,290 00
March 3, 1885, transfer to harbor at New Orleans	$900 00	
Expended to June 30, 1885	7,573 92	
		8,473 92
Balance on hand July 1, 1885		3,816 08

BONNET CARRÉ CREVASSE.

November 16, 1882, allotment from appropriation for improving Mississippi River, no limit; for closing Bonnet Carré Crevasse:		
Act passed August 2, 1882		$15,000 00
February 22, 1883, expended in one payment		15,000 00

IMPROVING HARBOR AT NEW ORLEANS, LOUISIANA.

Aggregate expenditures on work before it was placed under the Commission		$112,206 19
Balance on hand July 1, 1882		147,793 81
Disbursements since work was placed under the Commission:		
Expended to June 30, 1883		5,167 53
Balance on hand July 1, 1883		142,626 28
Expended to June 30, 1884		55,163 82
Balance on hand July 1, 1884		87,462 46
Expended to June 30, 1885	$87,006 35	
Covered into Treasury	123 42	
		87,129 77
Balance on hand July 1, 1885		332 69

Act of Congress approved July 5, 1884, for improving Mississippi River, no limit:

February 27, 1885, transfer of allotment for Red River to New Orleans Harbor	$900 00	
Expended to June 30, 1885	636 12	
Balance on hand July 1, 1885		$263 88
Total balance on hand July 1, 1885		596 57

OBSERVATIONS AT CARROLLTON, LOUISIANA.

November 19, 1882, allotment from appropriation for improving Mississippi River, no limit; for observations at Carrollton, La.:

Act passed August 2, 1882	$3,000 00
Expended to June 30, 1883	2,744 26
Balance on hand July 1, 1883	255 74
Expended to June 30, 1884	255 74

June 25, 1883, allotment from appropriation for the Mississippi River Commission:

Act approved March 3, 1883, for observations at Carrollton, La.	1,500 00
Expended to June 30, 1883	491 00
Balance on hand July 1, 1883	1,009 00
Expended to June 30, 1884	963 11
Balance on hand July 1, 1884	45 89
Expended to June 30, 1885	45 89

CUBITT'S GAP AND VICINITY.

September 17, 1882, allotment from appropriation for improving Mississippi River, no limit; for survey of Cubitt's Gap and vicinity:

Act passed August 2, 1882	300 00
Expended to June 30, 1883	137 14
Balance on hand July 1, 1884	162 86
Balance on hand July 1, 1885	162 86

Approximate value of plant belonging to the United States and used upon the construction and repair of levees, Fourth District.

Class of property.	Approximate value June 30, 1885.
Tools and appliances	$2,000 00
Office furniture	400 00
Surveying instruments	60 38
Miscellaneous	1,162 37
Total value	3,622 75

Approximate value of plant belonging to the United States and used upon the improvement of harbors of Natchez and Vidalia.

Class of property.	Approximate value June 30, 1885.
Tools and appliances	$250 00
Office furniture	15 00
Miscellaneous	6 50
Total value	271 50

Approximate value of plant belonging to the United States and used upon the improvement of mouth of Red River.

Class of property.	Approximate value June 30, 1885.
Steam-launch Ruby	$3,500 00
Two quarter-boats	2,245 40
Six skiffs and row-boats, &c	135 00
Tools and appliances	55 00
Office furniture	115 00
Surveying instruments	970 75
Miscellaneous	491 00
Total value	8,512 [illegible]

Approximate value of plant belonging to the United States and used upon the improvement of New Orleans Harbor.

Class of property.	Approximate value June 30, 1885.
Steamer General Newton	$12,900 00
Steam-tug Tilda	4,500 00
Steam-launch Alaska	2,700 00
Fifteen barges	23,700 00
One skiff, row-boat, &c	25 00
Tools and appliances	1,900 00
Office furniture	25 00
Surveying instruments	11 11
Miscellaneous	69 67
Total value	45,830 78

Approximate value of plant belonging to the United States and used upon the survey of unleveed fronts, Fourth District.

Class of property.	Approximate value June 30, 1885.
Tools and appliances	$0 50
Miscellaneous	20
Total value	70

Approximate value of plant belonging to the United States and used upon the observations at Carrollton, La.

Class of property.	Approximate value June 30, 1885.
Tools and appliances	$0 80
Office furniture	80
Total value	1 60

Approximate value of plant belonging to the United States and used upon the survey of Cubitt's Gap and vicinity, June 30, 1885: No property.

K 1.

REPORT OF ASSISTANT ENGINEER H. S. DOUGLAS UPON CONSTRUCTION AND REPAIR OF LEVEES IN THE FOURTH DISTRICT.

UNITED STATES ENGINEER OFFICE,
New Orleans, La., June 16, 1885.

SIR: I have the honor to submit the following report on the construction and repair of levees from October 1, 1884, to the close of the fiscal year ending June 30, 1885:

At date of last report bids for work on the following levees had been opened:

	Cubic yards.
Point Pleasant, about	22,000
Shipp's Bayou to Hard Times, about	38,000
Bondurant, about	35,000
Kempe Crevasse, about	25,000
Lake Concordia, about	31,000
Hardscrabble, about	75,000

It was stated that the amount in Lake Concordia Levee was liable to be materially increased, as the flood of 1884 had proved it to be entirely too low, and it was proposed, if possible, to raise it about 2 feet, with a corresponding increase of cross-section.

Awards based on the bids received were duly made and approved, and by October 10 embankment construction was in progress on nearly all the levees. The hard experience of two previous years was brought to bear upon the work. New and better specifications had been adopted and some changes were made in the method of supervising levee construction.

A rigid enforcement of the various contracts soon brought any of the contractors who were not disposed to prosecute the work with due diligence to terms, and the result was that the work progressed smoothly and with scarcely an incident worthy of note, until the various levees were completed, frequently in advance of the contract time.

The working season just past may be said to have been a good one.

The supply of labor was plentiful, and, until the middle of December, the weather favorable. There was but little sickness among those employed, probably owing to the dryness of the season. The injury to levees caused by traffic over them has been mentioned in previous reports, and in order to prevent this, at least until the embankments were thoroughly grassed and settled, barbed-wire fences were built across the levees. These fences extended from the foot of the slope on the land side to the foot of the slope on the river side, and were built at intervals of about 500 feet.

I give progress on each levee:

TENSAS FRONT.

Point Pleasant.—The lowest bidder for this work failed to qualify, and ultimately the contract was awarded to the next lowest bidder. This entailed some delay, and the work was not commenced until about November 17. It was then, however, prosecuted with vigor, and the work, consisting of gaps in the new levee caused by the flood of 1884, completed and received January 30.

SHIPP'S BAYOU TO HARD TIMES.

Embankment construction was commenced about October 15, and all of the levee except the "sinking portion" was completed and received December 31. This sinking portion has been mentioned in previous reports as giving a great deal of trouble. It was hoped that the sinking had ceased and a solid foundation been reached, but this hope was disappointed. A force was kept at work on this sinking part until lack of funds necessitated a suspension of operations, when final settlement was made with the contractors. Later on a transfer of funds was made from the Atchafalaya Front, and arrangements made for the continuance of the work, using wheel-scrapers and teams, as the earth had to be hauled a long distance. Slow progress was made towards completion, as the sinking continued. Finally, on June 20, the sinking having apparently ceased, work was suspended. It is not improbable next season's high water will cause the sinking to re-commence.

Evergreen.—This levee connects the United States Hard Times and Hardscrabble levees. Its construction was undertaken by the parish of Tensas. Their funds were exhausted when about two-thirds of the levee had been built, and it was feared that there would be a gap in the line of levees at this point. The matter having been

brought to the attention of the Commission, they made an additional allotment to construct that portion of the levee which the parish was unable to build. Notification of this allotment was received December 24, and authority was given, on account of the lateness of the season, to ask for informal bids. This was done, and the contract awarded to the lowest bidder. Embankment construction was commenced January 10. An early rise of the river brought it over the banks and against the levee before its completion, and a portion of the river base was thrown up to keep the water out. Rainy weather interfered considerably with the progress of the work, but the levee was finally completed March 2.

Hardscrabble.—Work on this levee by hired labor had been in progress from the annulment of the original contract until the high water of 1884. The overflow of that year having caused a heavy deposit in the swamp through which the levee passes, and changed to some extent the character of the work, it was thought a favorable bid could be obtained. It was accordingly advertised, and awarded to the lowest bidder. Embankment construction commenced on October 10, with a very small force. Some trouble was experienced in getting a proper force placed upon the levee, and it was only when extreme measures were resorted to that a sufficient number of men were placed upon the work. After this no further trouble was experienced, and rapid progress was made until the completion of the levee, December 31.

Bondurant.—The levee previously built by the United States at this point caved into the river for a length of about 1,200 feet on the subsidence of the high water of 1884, and a new line, or run-around, was staked out to close the gap. Work was commenced about October 8, and pushed with energy until completion of the levee, December 20. At the time when the levee was located the point at which the lower wing joined the existing levee was 1,000 feet from the river bank. Since the completion of the run-around the caving has been extraordinarily rapid. On May 11 an inspection was made, when it was ascertained that the point before mentioned was but 175 feet from the edge of the bank, which was still caving rapidly. It is almost certain that a portion of the old and new levees will cave into the river, and occasion a gap in the line of levees at this point.

Kempe Levee.—Previous to the opening of bids for work on the other levees, preparations had been made for the resumption of work on this levee by hired labor. On October 1, embankment construction was commenced. The rather severe experiences gained during the winter of 1884–'85 were borne in mind, and the result was an improved system and organization. Rapid and satisfactory progress was made, and this levee, which had given so much trouble, was completed January 10. A small force was kept at work on a portion of the levee across Potter's Slough, where the embankment sinks as at Hard Times. Lack of funds caused a suspension of work at this point on February 11.

Additional work is required at this place, as it is now the weakest point on the levee.

Kempe Crevasse.—This was a gap in the finished portion of the new Kempe Levee occasioned by the breaking of the protection levee during the flood of 1884. A run-around was staked out to close it, and work by contract commenced October 8. Rapid progress was made and the levee was finished November 29.

Lake Concordia.—This long line of levee was completed by the United States in the spring of 1883. The flood of 1884 breached it at several places, the breaks being caused by the water running over the levee. Work by contract for the closure of these gaps was commenced October 10. The low bids received on the various levees left an unexpectedly large balance of available funds, and it was decided to apply them, so far as they would go, to the enlargement of the existing levee, it evidently being too low. This was done accordingly, and all work at this levee for which funds were available was completed and received January 17.

ATCHAFALAYA FRONT.

The flood of 1884 had damaged some of the United States levees on this front to a considerable extent. The work necessary for their repair was not of a character that could be done by contract, and authority was obtained to do the work by hired labor. An overseer was placed in charge of a small force and all of the necessary repairs made.

At Red River Landing three bad sloughing places and about 1,000 feet of the levee that had been badly wave-washed were repaired in a substantial manner. At the Raccourci Levee a short piece of new embankment was built to cut off a bad crayfish hole, and numerous sloughing places and wave-washes were repaired.

At the Pointe Coupée (Scott) Levee the sloughing places were repaired in a thorough manner, and the sinking place across the old lake was raised. The result of the work has been to place the United States levees on this front in first-class condition.

KEMPE BEND SURVEY.

A resolution of the Commission passed at their meeting on May 12 directed that a survey of the Kempe Bend be made, and that all information accessible concerning previous bank lines and surveys be added to the survey; also an estimate of the cost of the necessary revetment. The survey has been made accordingly, the information collected, the survey platted, and the report, with estimate, submitted.

There is little if any variety in levee work under ordinary circumstances, and my previous reports give about all the special features I have noticed. The work is chiefly of an administrative character so far as the assistant in general charge is concerned. I will state, however, that a report gives but a faint idea of the incidents, details, and responsibilities of work of this character. The flood-line of the high water of 1885 has been unusually low, and the new levees have scarcely been put to a test. Before the next flood can reach them they will have had ample time to become well sodded and settled.

All of the property, tools, utensils, &c., that were acquired during the continuance of levee work by hired labor have been transferred to a place of safe-keeping at the Government landing situated on the left bank of the river about 15 miles above Natchez, Miss. At this point a suitable storehouse has been built for the accommodation of the property, which has been thoroughly overhauled, painted, repaired, and otherwise placed in as good condition as possible.

SUMMARY OF WORK.

Actual length of levees built, in feet	46,340
Number of gaps closed	40
Number of cubic yards earth placed in embankment (approximate, on account of repair work and sink at Hard Times, which could not be measured)	311,000
Approximate number of men employed per day when work was in progress on all levees	1,500

This work, together with what has been done by the State and parishes, has resulted in the closure of all gaps on the Tensas Front in the fourth district, except Diamond Bend, Bougere, and Black Hawk, to Red River. On the Atchafalaya Front all the United States levees have been placed in good condition, and the only gap on that front is the Morganza Crevasse. In general terms it may be stated that the levees throughout the district are in more perfect condition than they have been at any time for the past twenty years. It is gratifying to be able to make this statement, more especially as it is likely to be some time before work of this character is resumed by the General Government.

Very respectfully, your obedient servant,

H. S. DOUGLAS,
Assistant Engineer.

Maj. AMOS STICKNEY,
Corps of Engineers, U. S. A.

K 2.

REPORT OF ASSISTANT ENGINEER H. S. DOUGLAS UPON THE SURVEYS IN THE FOURTH DISTRICT.

SIR: I have the honor to submit the following report on the survey of the Kempe Bend, Tensas Parish, Louisiana.

The survey was made in accordance with a resolution of the Mississippi River Commission, passed at their meeting May 12, 1884, providing that the survey be made and that all information accessible concerning previous bank lines and surveys be added to the survey; also, an estimate of the cost of the necessary revetment.

The field work of the survey was commenced November 21, 1884, and completed January 30, 1885. The work done consisted of a main traverse line on true meridian the full length of the bend, following the general course of the new levee; a shore or bank line connected with either end of the main traverse line; five lines of levels across the country about 4,000 feet apart, at nearly right angles to the river, extending back 10,000 feet from the main traverse line, and carried out to the river bank, where they were prolonged across the river by soundings. Data for the platting of of old bank lines and levees was obtained from the office of the Louisiana State Board of Engineers. That portion of the Mississippi River covered by the survey and known as the Kempe Bend is about 28,000 feet in length, and at high water, when the

sand bar or island is covered, has a width of about 9,000 feet. In 1866 there were no indications of a bend at this place, as the river then flowed through an almost straight channel with a uniform width of about 4,000 feet. On old maps this portion of the river is delineated as a straight reach instead of a bend. In 1867 the Davis-Bend cut-off made at a point about 36 miles above. This shortened the river temporarily about 20 miles. The rapid caving at Kempe, and in fact all along the front of Tensas Parish, may be traced to this cause.

Between 1866 and 1885 the survey indicates that the river by caving its banks has destroyed 76,000,000 square feet, 1,747 acres of land. To accomplish this it has caved back at the deepest part of the bend a distance of 5,500 feet, destroyed the original comparatively high bank and eaten its way back into a low swamp, where levees of excessive height are now required to restrain the river and prevent an enormous escape of water from the channel. Owing to the rapid caving of the bank these levees are soon destroyed by the encroachments of the river, and new and expensive embankments are required.

Residents of the locality state that in the last twenty years $750,000 have been expended on levees in this bend.

So far as can be seen at low water the bank throughout the Kempe Bend is generally composed of a light sandy loam, which offers but little resistance to the current, and caving is continuous, both at high and low stages of the river. While the survey was in progress a deep hole was discovered in the river channel on one of the lines of soundings. In going over the same locality a few weeks after no trace of it could be discovered. This would indicate that the river bed is also composed of sand or some other material offering but little resistance to the scouring action of the water. The lines of levels which were run across the country indicate that the general elevation of the swamp behind the present levee is but little lower than where the present levee stands. While, therefore, it is not impossible to build another levee within a reasonable distance back of the present one, it will be a very expensive and difficult undertaking.

As directed, I submit the following approximate estimate for the protection of the existing bank and the prevention of further caving by means of submerged spur-dikes. The length of bank requiring protection at present is 25,000 feet, and with submerged spurs similar to those used in the improvement of New Orleans Harbor, located at intervals of about 1,000 feet, it is thought the desired result will be obtained. These spur-dikes are estimated to cost $10,000 each, or a total of $250,000 for the twenty-five estimated to be required for the protection of the bank in the Kempe Bend.

Should the present levee, recently completed by the Government, be destroyed by the caving of the bank a new levee on what appears to be the most feasible and safest line would be 30,000 feet long and with a grade 2 feet above the high water of 1884, 8-foot crown, and 3 and 3 to 1 slopes, would contain 665,000 cubic yards. Owing to the height of the bank and the low badly drained swamp through which the greater portion of the levee would be built, it would not be safe to estimate less than 30 cents per cubic yard as the cost of construction. At 30 cents 665,000 cubic yards would amount to $199,500. From present indications a portion of this levee will be required at the lower end of the Kempe Bend in a short time.

An inspection of the plat of the survey is of interest as showing the great changes that have taken place in the river at this locality. This plat is not completed in time to accompany this report, but will be finished in a few days.

Very respectfully, your obedient servant,

H. S. DOUGLAS,
Assistant Engineer.

Maj. AMOS STICKNEY,
Corps of Engineers, U. S. A.

K 3.

REPORT OF ASSISTANT ENGINEER A. O. WILSON UPON IMPROVEMENT OF THE MOUTH OF RED RIVER.

NEW ORLEANS, LA., *June* 15, 1885.

MAJOR: I have the honor to submit to you the following report on work done in the improvement of the mouth of the Red River, Louisiana, from October 1, 1884, the date of the last annual report to the "Commission," to date.

The Mississippi River had reached its lowest reading for the year on the Red River Landing gauge on October 1, being 6.3 feet. The river rose steadily from the 3d of October; it was necessary to continue the construction of the brush-dams perpendicular to the line of the channel in Lower Old River, on both sides, in order to scour

out the channel to its connection with the deep water at the head of the Atchafalaya River. The two propeller tugs were laid up at this point awaiting water sufficient to take them through Old River to the Mississippi, which it was an object to do, in order to return them to their owners at the earliest possible date. The force of twenty laborers and the small stern-wheel boat May Fisher were kept at work on the dams until October 7. The construction of the dams was of necessity very light, consisting of willow brush laid between two rows of poles driven down into the mud with a maul; the brush was weighted down with bags filled with sand. The dams could not be carried out far enough from the banks to create a channel for more than 500 feet below them, after which distance the current would spread out again and allow the hard sand lumps to form and obstruct navigation, whereas the channel between the dams was uniform in width and depth, with the bottom quite smooth. What caused these hard sand lumps in that part of the channel known as the Chandler reach, I cannot definitely state. Above Chandler's light we have sloughs in the banks, with mud lumps in the channel, and on the dry bar forming the low-water bank there are gas and water jets. Where the sand lumps are, no signs on either bank are visible of any disturbance, but parallel to the channel, on the north side of the dry bar, there is a large lake of water that at times is left standing considerably higher than the water in the channel. It is possible that this water may find its way through the bar, and, springing up in the bottom of the river, be the cause of the lumps, the concentrated current between the brush dams having power enough to scour out the sand lumps as fast as they can form. The river did not fall as low as last year by 2 feet on the Barbie's Landing gauge, 1.7 feet, on October 3, being the lowest reading. At this time we had a depth of 6 feet in the channel. I am satisfied that even had the water fallen as low as it did in 1883 we should have been able to maintain the channel by extending the dams. The operations of the season, though carried on at a little over half the expense of previous years, was successful, navigation having been kept open continuously for stern-wheel boats. This method, so successful this low-water season, cannot be relied upon always. The condition of things in general was more favorable for keeping a navigable channel open between the Mississippi and the Red and Atchafalaya rivers than in 1883. The current flowed in one direction without change from August 7 up to and after the suspension of operations. The sloughings or subsidences of the banks were not so large as those of last year. From the Mississippi to the Crossing there were slight subsidences on both banks for the whole distance. On the Atchafalaya side of the Crossing, near Chandler's light, there was a very large and remarkable subsidence on the main-land bank close under the high-water bank, and an enormous lump of mud came up, nearly blocking up the whole river; in fact, it only left a crooked channel 25 feet wide at the water surface. The peculiar feature of this slough was that the mud-flat, 300 or 400 feet in width, between the subsidence and the water's edge remained without the slightest sign of any disturbance having taken place. On the opposite side, for some distance above and below, the bar was all broken up in small perpendicular breaks, showing subsidence extending back from the water's edge for 300 feet. In this portion of the dry bar there had been gas and water jets which, after they had expended themselves, left a large shallow hole with a small deep round hole in the center. At Barbie's Landing only a slight settlement in the bank was evident.

On October 8 all the laborers, and the small stern-wheel boat May Fisher that had been used for towing willows and transporting the men, were discharged.

The Menge dredge was turned over to her owner October 8. The working of this dredge proved a failure. She was constantly broken down, and was not properly equipped, so that she could be held in position against the current. The two propeller tugs were brought out to the Mississippi River on the 10th of October against a terrific current and only water enough in the channel amounting to the bare draft of the tugs, which made it extremely difficult to keep them in the channel. On this day Barbie's Landing gauge read 5.9 feet, the surface of the Mississippi being 7½ feet higher at the mouth of Old River.

The idea that propeller tugs can create or maintain a channel by the scour resulting from their screws over a long shoal is a very serious mistake. The tugs employed were the two very best and most powerful of their size in America, and were worked faithfully twelve hours per day until they were ordered out of Old River, as there was danger from their being so thrown over on one side as to take in water through the engine-room door-way and settle on the bottom, in which case it might have been very costly to get them out, if not a danger of their being lost altogether, with so treacherous a bottom as that of the Lower Old River. On the short, sharp-crested sand-bar at the head of the Atchafalaya Bar, where they were afterwards worked, they did good service, but not without some danger, as the coal-bunkers had to be kept battened down to prevent their taking in water when careened by being forced up on the crest of the bar. The heavy drag-scraper, made up of four 250-pound anchors and the lip of a large dipper dredge, framed together with heavy timbers, and worked over the bow of the stern-wheel boat Gus. Geinn, was very effective in leveling

off the mud lumps into the deep holes and cutting through the mud-bar at the mouth of Old River. The last boat left the vicinity of the mouth of Red River, with the coal barge in tow, October 12, for New Orleans, where the steamboat was discharged, and the coal barge, with the coal remaining, was safely disposed of. Navigation remained good in Lower Old River until November 27, when the Mississippi had again fallen as low as 7.65 feet on the Red River Landing gauge, and continued falling until December 2, when it read 7.25 feet, and at the Barbie's Landing guage 3.9 feet. November 27 the United States stern-wheel boat Annie Kelly was got in readiness and left New Orleans for the mouth of Red River, where the drag-scraper was reframed and placed on the Annie Kelly, and work was resumed in the mouth of Old River November 30, as the examination of the day previous had shown this to be the worst place. There still remained enough of the brush-dams in Chandler's Reach to keep the channel there good.

December 8, navigation being good and the Mississippi rising, the Annie Kelly returned to New Orleans and was laid up. After the hired plant had been dispensed with, October 14, the quarter-boats and skiffs were repaired, and the coal taken out of the old sunken coal-barge: the gauges at West Melville, Simmsport, Barbie's Landing, and the mouth of Old River, were renewed and put in order for the high-water season. The Atchafalaya steamboats Warren and Fanchon kept running all the season; they report fairly what water they find, but reports of such boats as the Phil. E. Chappell, who run into the bank in the dark, tie up for the night, and then report in the papers as delayed in Old River twenty-two hours, "had to pull through," are not to be depended upon as correct. Since December 10 the work has consisted of office work only. A series of maps showing the proposed navigation route from the Mississippi River to the Red and Atchafalaya rivers through Bayou Plaquemine and Grand River have been prepared, consisting of a map of Bayou Plaquemine surveyed 1883; a map showing the whole of the proposed route; a general plan for a double lock at Plaquemine; a map of the Narrows in Grand River, with cross-sections from the survey of 1879; a profile of the center line of the proposed canal through Bayou Plaquemine, with a report on the work required, including the estimates of the cost, as previously presented by you to the Commission.

From March 1, to the present date no work has been done in connection with the improvement of the mouth of Red River, Louisiana. The services of the assistant in charge of the works were dispensed with, the property placed in the care of watchmen, and the quarter-boats and steamer Ruby removed from the mouth of Old River to Giles Bend, above Natchez, for greater economy and safe-keeping.

I am, respectfully, your obedient servant,

ARTHUR OWEN WILSON,
Assistant Engineer.

Maj. AMOS STICKNEY,
Corps of Engineers, U. S. A.

K 4.

REPORT OF ASSISTANT ENGINEER A. O. WILSON UPON THE PLAQUEMINE ROUTE.

UNITED STATES ENGINEER OFFICE,
New Orleans, La., February 20, 1885.

MAJOR: I have the honor to submit to you the following report, to accompany the maps, plan, and profile made under your direction.

At the meeting of the Mississippi River Commission, held in Saint Louis, Mo., September 14, 1882, the following resolution was passed:

"That Major Stickney, United States Engineers, be requested to submit an estimate of the cost of making a survey of the navigation route from the Mississippi River through the Bayou Plaquemine, and up the Grand and Atchafalaya rivers to the head of the latter stream, with a view to reporting upon the feasibility and cost of improving said route to replace the present access to Red River."

In accordance with the above, a project for a survey, with an estimate of the cost, was submitted by you, and at a meeting of the Mississippi River Commission, held in New Orleans, March 21, 1883, it was resolved that the project be adopted and recommended.

In accordance with the above resolution of the Mississippi River Commission preparations were made, and a party sent into the field to make a survey of the proposed "navigation route." The survey party went into the field early in June, 1883, the waters of the flood making it impracticable to commence field work any sooner. Owing to the extreme sickliness of the season and the death of Assistant

Engineer E. A. Szalla, who was in charge of the party, the survey was not carried beyond Bayou Plaquemine.

The canal part and locks, which form all the heavy work in connection with the route, are included in this survey. The survey of 1880–'81, made for the same purpose, of the remaining portion of the route furnishes all the information and data required, and from which the estimate of the widening at the narrow part of Grand River was made.

An estimate of the cost of making a route for navigation from the Mississippi through Bayou Plaquemine and up Grand and Atchafalaya rivers was presented to the Commission by you in December, 1883, appended to which were the reports of Assistant Engineer F. W. Lehnartz on the cost of the excavation in Bayou Plaquemine, and that of Assistant Engineer H. C. Collins on the cost of the locks at Plaquemine and the work required in Grand River.

The following additional, prepared under your direction, are now completed:

A map of the navigation route.

A map of the canal part.

A general plan for a double lock.

A map of the Grand River Narrows.

A profile on the center line of the canal through Bayou Plaquemine.

The map of the navigation route shows all the water-ways, large and small, including the Mississippi and Atchafalaya rivers, from the mouth of Red River to Plaquemine, on the Mississippi, and to Grand Lake.

This map is compiled from the parish maps of Pointe Coupée, West Baton Rouge, and Iberville, including parts of the parishes of Saint Martin's and Ascension, compiled in 1859 from the most authentic United States surveys, and indorsed by J. M. Culloh, Surveyor-General; from a map of the Atchafalaya and Pointe Coupée basins, made by John V. Van Pelt, civil engineer, in May, 1873, and from a map of the Atchafalaya River made from a survey of Assistant Engineer F. P. Leavenworth, under the direction of Maj. C. W. Howell, United States Army, in 1874.

The map is made on a scale of 1 inch to a mile, in order to illustrate the whole route and the character of the country through which it runs.

The map of the canal part, through the Bayou Plaquemine, is made from the survey by Assistant Engineer E. A. Szalla, June to September, 1883. The map shows the proposed location of the canal and the site for the locks in Plaquamine town. The estimate for the excavation is made from the cross-sections of Bayou Plaquemine, on the basis for a channel 150 feet wide on the bottom and a depth of 5 feet at low water, with side slopes of 3 horizontal to 1 vertical, and the curvature limited, to a minimum radius of 1,500 feet on the center line. This map extends over all that part of the bayou requiring enlargement, and is made on a scale of $\frac{1}{6000}$. The map shows the channel, 150 feet wide on the bottom, located as estimated upon by Assistant Engineer F. W. Lehnartz. The general plan for a double lock as estimated upon by Assistant Engineer H. C. Collins.

The plan, as presented, is to show the character of the structure proposed as the most suitable to the locality and adapted to the requirements of navigation. The nature of the ground is such as to require a structure with its weight as equally distributed over the area on which it is built as possible.

The lock-chambers show a length of 300 feet between the gates with a width of 75 feet. The plan provides for a guard-gate at the Mississippi entrance.

The walls of the first chamber will have a height of 40 feet, giving a depth of 6 feet on the floor at low water. The extreme difference between the highest water in the Mississippi and the level of the lowest in Grand River, at the mouth of Bayou Plaquemine, is 32 feet, as stated by Mr. H. C. Collins in his estimate on the cost of the locks, so that the top of the walls will be 2 feet above the highest known flood, with guard-timbers carried 10 feet higher. The walls of the second or lower chamber are to have a height of 25 feet from the floor. This chamber it is proposed to use alone for all stages from low water up to 15 feet, after which and up to extreme high water the upper or first chamber is to be used for the passing of boats up from and down to the lower chamber and the Mississippi at the high stages, or whenever the Grand River shall have attained a stage equal to over 15 feet in the Mississippi River. Only the upper or first chamber will be used. There will be times when the lockage is down into the Mississippi. Provision is made for this in the plan. The gates proposed are of iron; the lock-chambers will be filled through wickets in the gates. It is proposed to make the gates on the general plan of the wheeled gates for Davis Island Dam.

The profile taken on the center line of the canal, as laid down on the map of the canal part.

The profile shows the depths of cutting required on the center line of the canal from the Mississippi through Bayou Plaquemine to its junction with Bayou Grosse Tête, beyond which point navigation is good up to the Narrows in Grand River.

MAP OF THE GRAND RIVER NARROWS.

This map, with the cross-sections, shows the work required to make this part of Grand River equal in point of navigation to the other portions of the route. The heavy lines on the map and cross-sections indicate the channel 150 feet wide at low water, and the broken lines indicate the 200-feet-wide channel, as estimated for.

This map and cross-sections are made from the survey and examination made in 1880 and 1881 by Assistant Engineer H. C. Collins, who also made the estimate submitted.

The estimates for the navigation route, as presented by you to the Mississippi River Commission in December, 1883, are as follows:

TWO LOCKS.

Brick walls	$531,550 00
Concrete walls (Portland cement)	479,600 00
Concrete walls (Rosendale cement)	401,650 00
Concrete walls (Louisville cement)	384,950 00

EXCAVATION IN BAYOU PLAQUEMINE.

3,557,720 cubic yards, at 20 cents	711,544 00
Contingencies, 10 per cent	71,154 40
	782,698 40

CHANNEL IN GRAND RIVER 200 FEET WIDE, 5 FEET DEEP.

Excavation, 1,257,000 cubic yards, at 20 cents	251,400 00
Grubbing 61 acres, at $75 per acre	4,575 00
Clearing banks 20 miles, at $200	4,000 00
Contingencies, 10 per cent	25,997 50
	285,972 50

CHANNEL IN GRAND RIVER 150 FEET WIDE, 5 FEET DEEP.

Excavation, 631,064 cubic yards, at 20 cents	126,212 80
Grubbing 31 acres, at $75 per acre	2,325 00
Clearing banks 20 miles, $200 per mile	4,000 00
Contingencies, 10 per cent	13,253 78
	145,791 58

REMOVING RAFT AND SNAGS IN ATCHAFALAYA RIVER.

Snag-boat	60,000 00
Two seasons' work, eight months each, at $3,000	48,000 00
	108,000 00

Aggregate cost of route.

Items.	Brick locks.		Concrete locks.	
	Grand River Channel 200 feet.	Grand River Channel 150 feet.	Grand River Channel 200 feet.	Grand River Channel 150 feet.
Locks	$531,550	$531,550	$479,600	$479,[illegible]
Bayou excavation	782,700	782,700	782,700	782,[illegible]
Grand River	286,000	145,800	286,000	145,[illegible]
Removing raft and snags in Atchafalaya River	108,000	108,000	108,000	108,[illegible]
Total	1,708,250	1,568,050	1,656,300	1,516,[illegible]

I am, very respectfully, your obedient servant,

ARTHUR OWEN WILSON,
Assistant Engineer.

Maj. AMOS STICKNEY,
Corps of Engineers, U. S. A.

K 5.

REPORT OF ASSISTANT ENGINEER W. G. PRICE UPON WORK IN NEW ORLEANS HARBOR.

NEW ORLEANS, LA., *May* 18, 1885.

MAJOR: I have the honor to make the following report of work in New Orleans Harbor during the low-water season of 1884.

It having been decided to begin the work of putting down submerged spurs at Gouldsboro', plans, and estimates of material required, were prepared.

Three decked barges were constructed by contract and delivered August 28. The stern-wheel tow-boat Anne Kelly (name since changed to General Newton) was purchased August 23, and was employed in towing barges of rock from Wilson's Point, Louisiana, to Gouldsboro'. The plant in use in Carrollton Bend in 1883 was improved and put in order for the new work. A survey of Gouldsboro' Bend was completed in July. On August 24 the plant was towed to Gouldsboro', and on the 29th the construction of the first spur was begun. The work of constructing and sinking spurs was done by hired labor. The willow brush, lumber, bolts, chains, &c., were delivered by contractors. Stone was purchased at Chester, Ill., by Capt. J. H. Willard, Corps of Engineers, United States Army, and sent down on chartered barges. A small amount of ballast was also purchased in the harbor. Several delays, which increased the cost of the work, were caused by the slow delivery of material by contractors. The mattress for each spur was 200 feet wide up and down stream, and extended 350 feet out in the river. It was woven of willow brush and poles and had iron rods and chains woven in it to give the necessary strength required in sinking it. A narrow crib-work filled with rock was built on the edge round three sides of it.

While sinking the mattresses it was supported on three sides by double lowering lines 1 inch in diameter, placed 16 feet apart, and the shore edge was fastened with iron rods to logs buried in the ground. Each lowering line passed up over the rounded gunwale of a decked barge, then once around a timber head, and was fastened to a messenger rope which was carried round capstan near the shore.

One man payed out the messenger which controlled all the lowering lines so that none were unduly strained. The mattress was held against the current by six large ropes which were fastened to the upper edge by toggles and were carried diagonally up-stream to the bank. The mattress was heavily ballasted round the edges and just enough rock was put elsewhere to put it out of sight, great care being taken not to load it too heavy, then it was lowered to the bottom and more rock thrown on. The ballasting was done entirely from a barge, no rock being wheeled on. In lowering, the up-stream edge was allowed 10 feet start of the down-stream edge, and then they were lowered an even amount till both were on the bottom. On a line parallel with the up-stream edge of the mattress and 70 feet below it there were sunk, one on another, six cribs each 5¾ feet thick. The bottom crib had a width of 60 feet and the top one 22 feet. The bottom crib was short and they increased in length so that the top of the last one was about on a slope of 3 horizontal to 1 vertical from the low-water shore-line, and it extended 300 feet out in the river. The method of sinking the cribs was the same as for as the mattress except that they were heavily ballasted before lowering to the bottom. The spur was built out at right angles to a line drawn tangent to the curve of the bank. The cribs were built on timber-ways on the bank and launched. They consisted of a frame-work made of sawed timbers held together with long iron bolts and wooden posts fastened with wooden pins and filled with willow brush, leaving pockets into which to throw the stone. The mattresses and cribs for two complete spurs and a mattress and three cribs towards another were successfully made and sunk to the correct position without accident.

In sinking the mattress 7 pounds of rock weighed in water was used for each square foot of surface.

In sinking the cribs 7 pounds of rock weighed in water was used for each cubic foot of crib-work.

The average cost of a complete spur, not including cost of plant, was $12,525.

Mattresses with crib-work round edges of them cost 7.6 cents per square foot when ballasted and sunk.

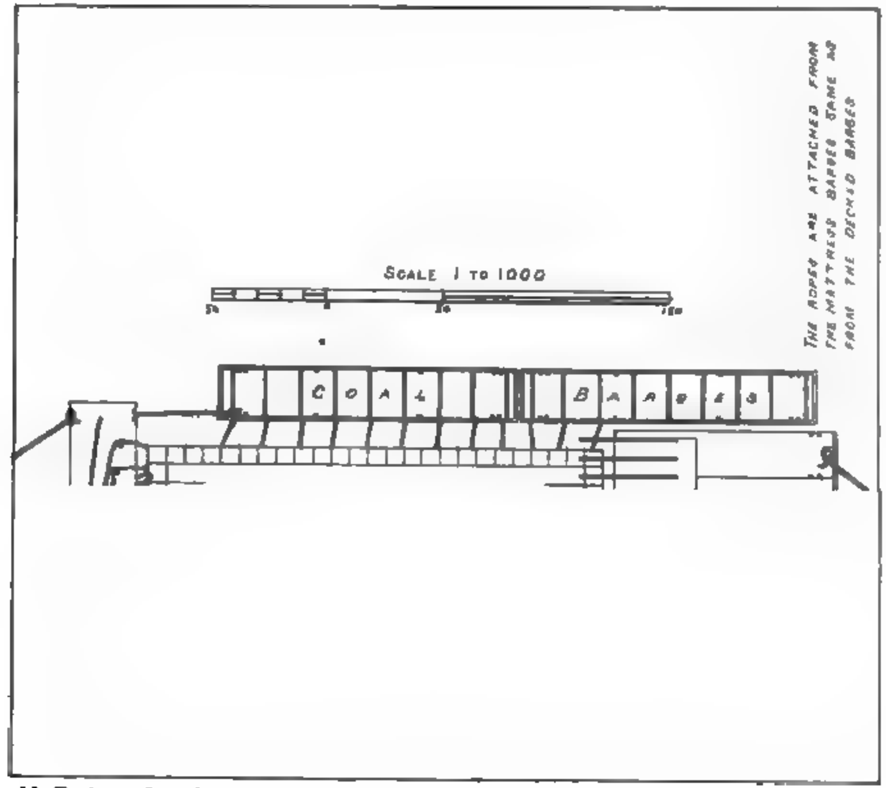
Crib-work of spurs cost 3.6 cents per cubic foot when ballasted and sunk. Experience gained would enable us to greatly reduce the cost of future work of this kind.

The work was stopped November 28, the appropriation having been exhausted.

Respectfully submitted.

W. G. PRICE.

PLATE No. 5


SCALE 1 TO 1000
COAL BARGES
THE ROPES ARE ATTACHED FROM THE MATTRESS BARGES SAME AS FROM THE DECKED BARGES

APPENDIX X X.

REPORTS OF THE MISSOURI RIVER COMMISSION.

X X 1.

REPORT FOR 1884.

WAR DEPARTMENT,
Washington City, January 7, 1885.

In accordance with the act of Congress approved July 5, 1884, creating the Missouri River Commission, the Secretary of War has the honor to transmit herewith to the United States Senate the annual report of said Commission for 1884.

The recommendations of the Commission for appropriations for the fiscal year ending June 30, 1886, have been forwarded to the Secretary of the Treasury for transmission to Congress, as required by section 2 of the act of July 7, 1884. (Pamphlet Laws U. S., 1883–'84, page 254.)

ROBERT T. LINCOLN,
Secretary of War.

The PRESIDENT PRO TEMPORE OF THE SENATE.

REPORT.

MISSOURI RIVER COMMISSION,
Saint Louis, Mo., December 9, 1884.

SIR: The Missouri River Commission, created by the act of July 5, 1884, is required by law to submit annually for transmittal to Congress, at the beginning of the regular session in December, "a full and detailed report of all their proceedings and actions, and of all such plans and systems of work as may now be devised and in progress and carried out by them, and of all such additional plans and systems of work as may be devised and matured by them, with full and detailed estimates of the cost thereof, and statements of all expenditures made by them."

The duties prescribed to the Commission by the same act were—

To superintend and direct such improvement of said river, and to carry into execution such plans for the improvement of the navigation of said river from its mouth to its headwaters as may now be devised and in progress, and to continue and complete such surveys as may now be in progress, and to make such additional surveys, examinations and investigations, topographical, hydrographical, and hydrometrical, and to consider, devise, and mature such additional plan or plans, and all such estimates as may be deemed necessary and best, to obtain and maintain a channel and depth of water in said river sufficient for the purposes of commerce and navigation, [and] under

the direction and with the approval of the Secretary of War, superintend, control, and expend for the purposes of this act all appropriations or unexpended balances heretofore made for the improvement of said river, and which may hereafter be made for said river, or so much thereof as may be necessary.

In the same act were the following items, appropriating money for the execution of these duties:

(1) Improving Missouri River from its mouth to Sioux City, Iowa, including such harbors on said river as, in the judgment of the board of engineers herein created, will benefit commerce and navigation, $500,000.

(2) Improving Missouri River from Sioux City, Iowa, to Fort Benton, Mont.: Continuing improvement, $125,000; of which sum $15,000 shall be used in the purchase of a snag-boat to be operated on the Missouri River above Sioux City, and on the Yellowstone River.

(3) For a survey of the Missouri River above the Missouri River Falls, at Fort Benton, $15,000.

Upon assuming their duties, the Commission found that a continuous survey of the river had been made from its mouth to Fort Pierre, Dak., a distance of 1,174 miles, and also from the mouth of Sun River, at the head of the Falls, to Stubbs Ferry, near Helena, a distance of 130.7 miles, leaving unsurveyed the portions extending from Fort Pierre to the mouth of Sun River, a distance estimated at about 1,390 miles, and from Stubbs Ferry to the headwaters of the Missouri, at Three Forks, a distance estimated at 73 miles. They found that the head of navigation was at Fort Benton, situated about 250 miles below the headwaters, and about 2,519 miles above the mouth of the river; that works of improvement had been executed at various points from Saint Charles, Mo., 25 miles above the mouth, to Kipp's Rapids, 58 miles below Fort Benton, besides some small works constructed in 1880 above the Falls.

For convenience of administration, the river had been divided into two districts, the first district extending from the mouth to Sioux City, a distance of 803 miles, and the second from Sioux City to Fort Benton, a distance of about 1,716 miles. The division was an artificial one, made simply for convenience, there being no marked change in the character of the river for a long distance above and below Sioux City.

SIOUX CITY TO THE MOUTH.

Maj. Charles R. Suter, Corps of Engineers, U. S. A., was in charge of the first district. The first works undertaken by the Government in this district were at Eastport, Iowa, and Saint Joseph, Mo., under small appropriations made in 1876. Subsequently other appropriations were made for these and other localities, the number of the latter being increased from year to year, until in 1881 the number of separate localities provided for was thirteen. Their names and distances from the mouth of the river, with the date of first appropriation, are as follows: Saint Charles, Mo., 25 miles, 1880; Cedar City, Mo., 147 miles, 1879; Glasgow, Mo., 226.5 miles, 1879; Lexington, Mo., 319 miles, 1880; Kansas City, Mo., 386 miles, 1879; Fort Leavenworth, Kans., 419 miles, 1878; Atchison, Kans., 446 miles, 1878; Saint Joseph, Mo., 479.5 miles, 1876; Brownville, Nebr., 580 miles, 1880; Eastport, Iowa, and Nebraska City, Nebr., 608.5 miles, 1876; Plattsmouth, Nebr., 638 miles, 1880; Council Bluffs, Iowa, and Omaha, Nebr., 668 miles, 1878; Sioux City, Iowa, 803 miles, 1878. Obviously there could be no connection between these works. As a general rule each had to be provided with a separate plant and separate engineering staff. Previous to and including the appropriation bill of 1881, there had been five bills, containing altogether forty-three items, appropriating money for the thirteen localities. Of these forty-three

items, thirteen amounted to $10,000 each or less, twenty were greater than $10,000 and not greater than $20,000 each, seven were greater than $20,000 and not greater than $30,000 each, while there was one item of $40,000, one of $50,000, and one of $80,000. The aggregate of these appropriations is large, amounting to $861,000, but no useful results, at all justifying such an expenditure, were obtained or could be obtained under the system. The means were inadequate at nearly every point, nothing could be finished, and the incomplete work was an easy prey to the destructive forces of the river. At the same time the supervision of so many works, so widely scattered, required a large and expensive administrative staff.

In the mean time a general survey of the river, begun under an appropriation made in 1878, was progressing. By the 2nd of February, 1881, it had been so far completed and its results so far studied by Major Suter as to enable him upon that date to make a report and project for the general improvement of the river from its mouth to Sioux City. This report was followed by an appropriation in the act of August 2, 1882, of $850,000, in which the ruinous system of allotting small sums to widely separated localities was abandoned, and the beginning of a systematic improvement of the river was first rendered possible. Under this appropriation some of the more important of the works previously undertaken were continued, but a very large portion of it was devoted to the preparation of the machinery and other plant required for conducting the works upon a large scale. This plant is now available for use. The next appropriation was that of 1884, with the expenditure of which this Commission are charged.

The report of Major Suter, dated February 2, 1881, gives a full description of this portion of the stream, and being already in the hands of Congress, renders it unnecessary for the Commission to go into details in that respect at this time. It is to be found in the Annual Report of the Chief of Engineers for 1881, beginning on page 1649. The general plan therein proposed contemplates contracting the width of "the river bed to such limits as will insure stability of regimen and approximate uniformity of slope, width, and depth." The Commission approve and adopt this plan. They approve also the methods proposed for carrying it out, subject to such modifications and changes as future experience may dictate. They are not prepared at this time to submit an estimate of its cost. They can only express their opinion that the work is physically practicable. The question of cost must be determined by actual trial. The immense advantages to be gained from success justify the expenditure of a large sum in making the trial. The experiments heretofore made have many encouraging features. Their want of cohesion is sufficient explanation of their want of success. The trial, to be really demonstrative, must be undertaken with ample means and followed up without intermission for several years, over a continuous piece of river, the length of which must be considerable. It is the opinion of the Commission that the work, while in the experimental stage, should be carried on under annual appropriations of $1,000,000 each, and they accordingly recommend for the coming year for this portion of the river an appropriation of $1,000,000.

It remains to announce the principles by which they have been governed in making the allotments for carrying on the works and which they propose to follow in the future, where the appropriation bills leave such allotments to their discretion. The Commission find that among the people most interested in the improvement of the Missouri River there are two radically different views as to the proper method of dis-

tributing the appropriations. On the one hand it is held that the first and most important object of the appropriations is to check the ravages now being suffered by private, corporate, and municipal property on the banks; that an appropriation made by law to apply to a long reach of river should be distributed somewhat uniformly over it, due attention being paid to the relative value of the interests endangered at different points; that the commerce now actually existing upon the river is of small importance, and that works for its exclusive benefit may well be deferred until the tangible property now visible be secured from injury. Naturally the persons holding these views have most frequently and most vigorously made themselves known to the Commission.

On the other hand, it is held by the Commission that the appropriations are intended as a business investment made by the Government with the object with which any other capitalist enters upon a great enterprise, viz, a return of the capital together with interest; that the primary object of the improvement is to deepen the channel and thus to provide cheap *through* transportation for freight by which the country may be developed and the money paid out be finally returned to the Treasury of the United States; that the cost of protecting any portion of the bank from erosion is so great that it is only in exceptional cases that the annual interest upon the investment does not exceed the annual loss without protection; that while it is true that there is but a small amount of commerce upon the river at this time, the object is to increase that commerce, and that if that object fails the whole scheme is a financial failure whether the destruction of property may have been stopped or not; and, finally, that to distribute the appropriations over numerous points separated from each other by long distances is to insure greater expense in the use of plant and in administration, to postpone the realization of any benefits from the partially completed improvement, and probably also to have insufficient means at all points, with the disastrous results that have heretofore attended that policy.

Holding these views, the Commission have determined to concentrate their means and to apply them where there is the best promise of obtaining substantial benefits to the general commerce of the United States, at the earliest practicable date, and before the entire completion of the improvement. Evidently useful results can be most quickly obtained by improving the lower end of the river, providing an outlet to the Mississippi. Engineering necessities require that the work should progress down-stream. The initial point must, therefore, be at some distance above the mouth. The Commission have selected Kansas City, 386 miles above the mouth, because it is the first important commercial center to be met with in proceeding up-stream. They would have preferred an initial point at a less distance from the mouth than 386 miles, but believing that no very great benefit would be conferred upon the commerce of the United States before the improvement shall extend from the mouth to Kansas City, they have allowed the following considerations to control, viz, that it was desirable to begin the work near a good base of supplies, and that some detached work had already been done here under previous appropriations which could be utilized as part of a general scheme of improvement.

The larger portion of the appropriation for the portion of the river below Sioux City has been allotted to the works to be executed at and below Kansas City. The programme which the Commission have adopted is to make the improvement continuous, working down-stream from Kansas City to the mouth of the river, applying all the means placed at their disposal, as far as possible, to this purpose, protecting

land and building up new banks as this becomes necessary for the preservation of the channel.

It was found, however, that at Saint Joseph, Mo., a cut-off was threatened which, if made, would have a far-reaching and injurious effect upon the stream, and that moreover there was a considerable amount of work there in place, executed under former appropriations, which, if left to itself, would be lost. These two circumstances combined seemed to justify making an exception in this case to the general rules established, and it was accordingly determined to complete the revetment of the banks in this vicinity. One or the other circumstance alone occurs elsewhere, but does not, in the judgment of the Commission, justify a departure from the systematic plan proposed.

SIOUX CITY, IOWA, TO FORT BENTON, MONTANA.

The second district had been under the charge of Capt. Edward Maguire, Corps of Engineers, U. S. A., until April 15, 1883, and after that date under Capt. James B. Quinn, of the same corps.

In the upper portion of this district the Missouri River flows through a bed composed of rock and gravel. In this rocky portion work can be carried on at detached points with the full expectation that each obstacle removed will be of permanent benefit to navigation. No continuous survey has ever been made except for the lower 371 miles between Sioux City and Fort Pierre. The works of improvement have been confined to the rocky portion, extending from Fort Benton to Carroll, a distance of about 160 miles, with the exception of some works near Vermillion, Dak., about 50 miles above Sioux City, begun in 1879 and discontinued in 1882. They have consisted of removing rocks from the channel and of the construction of wing-dams, the most prominent obstructions being selected for removal, as funds from time to time became available. The first appropriation was made in 1876. Others were made in each subsequent river and harbor act, until the total amount appropriated previously to July 5, 1884, was $290,000. The works have greatly benefited navigation and seem to have covered nearly all the ground to which they are applicable. This fact, however, cannot be ascertained with certainty until the river shall have been surveyed. The Commission approve and adopt the plan heretofore followed in the "rocky river." Further work in this portion of the stream will consist of maintaining the present works, constructing others if required, and of dredging.

Below the "rocky river," that is, below Carroll, there is a long reach of river, extending to Fort Pierre, a distance estimated at about 1,145 miles, which for engineering purposes is practically unknown. Examinations have shown that the stream gradually assumes the sandy and shifting character and gradually earns the title of the "Big Muddy" which it possesses at Sioux City. They have shown also that the severity of the climate and the frequency of ice gorges are such, that the devices employed in the works at the lower end of the river may prove to be entirely inapplicable here. It is the opinion of the Commission that the survey of this portion of the river should be pushed to completion as rapidly as practicable, but that no extensive works of any kind should for the present be undertaken. They propose to inaugurate some experimental constructions, proposed by Captain Quinn, at a characteristic section selected near Bismarck, Dak.

The importance of continuing the survey of the river has rendered it necessary to allot to that purpose a considerable portion—$25,000—of

the appropriation now available. The remainder of that fund will be employed in the purchase of a snag-boat, a dredge-boat, and other plant, and in continuing the present plan of operations in the "rocky river."

The Commission recommend that the snag-boat be kept at work in removing snags and other obstructions from the present channel above Sioux City, and the wing-dams be kept in repair, and the dredge-boat be kept at work in the "rocky river," and that provision be made for the experimental construction to be undertaken near Bismarck. For these purposes they recommend for the Missouri River between Sioux City and Fort Benton an appropriation for the coming year of $160,000.

MISSOURI RIVER ABOVE THE FALLS.

The Commission are informed that no steamboat has ever been upon the river above the Falls. This obstacle, extending from a point 45 miles to a point 20 miles above Fort Benton, completely and permanently cuts off the extreme upper portion of the river from all open channel connection with the lower. Of the 204 miles of river between the Falls and the headwaters of the Missouri at Three Forks, 131 miles have already been surveyed, leaving unsurveyed the 73 miles immediately below the Three Forks. There seems to be no immediate necessity for further surveys in this portion of the river. The Commission have ventured to suspend the expenditure of the appropriation of $15,000 contained in the act of July 5, 1884, until the matter can again be brought to the attention of Congress. They recommend that the amount be reappropriated and made available for the general survey of the river from its mouth to its headwaters.

SURVEYS, ETC.

The continuation of the surveys and examinations contemplated in the law organizing the Commission is a matter of the first importance. It has been provided for during the current year by allotments from the general appropriations for improvements. But these operations, however necessary, do not offer tangible results in the way of improvement, while they constitute a heavy drain upon the appropriations made for the latter purpose. It would seem proper that they should be provided for separately. The same may be said of the traveling and office expenses and salaries of the Commission.

The Commission recommend an additional appropriation of $150,000 for these objects, and they suggest the propriety of attaching this item to the sundry civil bill, as is done in the case of the Mississippi River Commission.

PROGRESS MADE UNDER THE ACT OF JULY 5, 1884.

The Commission held their first meeting on the 2d of September, 1884, that being the earliest date at which they could be brought together after the designation of their president. The entire work of organizing, securing the services of disbursing officers, going through the necessary formalities of procuring the funds, making contracts for materials, moving the plant—that for the river below Sioux City being then stored over 400 miles from the initial point of the work—and collecting a large force of laborers with a due complement of skilled overseers, was before it. It was plainly impracticable to perform these duties, even in a hurried and unsatisfactory manner, in time to accomplish any important results before the advent of winter. It was accordingly determined to postpone the beginning of works of construction until the next season.

On the 7th of October, First Lieut. Walter L. Fisk, Corps of Engi-

neers, United States Army, reported for duty as secretary of the Commission. Surveying parties, under his direction, were placed in the field as soon as practicable, for the purpose of establishing permanent bench-marks and triangulation stations between Kansas City and the mouth of the river, this work being necessary to complete the surveys already made in that region. Details of the progress made in this work will be found in the report of Lieutenant Fisk, hereto appended, marked Appendix A.

A resurvey of a portion of the river bank near Kansas City, for purposes of comparison, was ordered, the results of which have not yet been received.

In response to a letter complaining that the bridge at Boonville, Mo., was a serious obstruction to navigation, the secretary of the Commission was directed to investigate the matter. His report is hereto appended, marked Appendix B, from which it appears that the complaint was not well grounded.

Under date of October 24, 1884, Capt. James B. Quinn, Corps of Engineers, United States Army, was detailed by the War Department to take charge under the Commission of the improvement of the river above Sioux City, taking station at Saint Paul, Minn. Application has been made to the War Department for the detail of an engineer officer, to take station at Kansas City, to take charge of the works between Sioux City and the mouth. The officers in charge of districts and the secretary of the Commission are its disbursing officers. They receive instructions as to the general execution of plans and details of work from the Commission, but in all matters relating to money accounts they report to the Chief of Engineers direct.

It is expected that the organization and other necessary preparations will be fully completed during the present winter, and that everything will be in readiness for beginning the works of construction in the spring.

A detailed statement of all the expenditures of the Commission to December 1, 1884, is hereto appended, marked Appendix C.

RECOMMENDATIONS.

The following is a recapitulation of the foregoing recommendations:

(1) Appropriation for the improvement of Missouri River from its mouth to Sioux City	$1,000,000
(2) Appropriation for the improvement of Missouri River from Sioux City to Fort Benton	160,000
(3) Reappropriation for the survey of the Missouri River, from its mouth to its headwaters, of the item of $15,000, appropriated in the act of July 5, 1884, for survey of river above the Falls	15,000
(4) Appropriation for survey, examinations, and investigations, and for traveling and office expenses and salaries of the Commission, with the suggestion that this item be attached to the sundry civil bill, as in the case of the Mississippi River Commission	150,000

Respectfully submitted,

CHAS. R. SUTER,
Major of Engineers, U. S. A.,
President Missouri River Commission.
A. MACKENZIE,
Major of Engineers, U. S. A.
O. H. ERNST,
Major of Engineers.
G. C. BROADHEAD.
WILLIAM J. BROATCH.

The Hon. SECRETARY OF WAR.
(Through the Chief of Engineers, U. S. A.)

APPENDIX A.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., December 1, 1884.

SIR: I have the honor to submit the following report of progress made since I reported for duty October 7, 1884, on "Additional surveys and establishment of permanent bench-marks," authorized by resolution of the Commission adopted September 4, 1884.

No previous report has been submitted, because the only work done before November 1 was the partial repairing of the steamer Missouri, which was under way when I reported, and the survey of the Missouri River in the vicinity of Kansas City, Mo., which the Commission, while in Kansas City, on the 9th of October, directed Mr. Yonge to make, and of which no report has yet been received.

The repairs of the "Missouri" were completed, and the boat reached Glasgow, Mo., on Saturday, November 8, where the permanent bench-mark party, under Assistant Engineer D. W. Wellman, joined her on Monday, November 10.

To this party has been assigned the work of establishing lines of permanent bench-marks across the valley of the river at average intervals of about 5 miles, the transferring of levels from existing bench-marks to them, and, in addition, the work of building stations and clearing lines for the triangulation parties, as the steamer furnishes convenient transportation and quarters for the necessary men and materials.

The bench-marks and triangulation stations are similar to those used by the Mississippi River Commission, and described in their annual report for 1883, p. 164. The organization and pay of this party are as follows, viz:

Permanent bench-mark party:		
1 assistant engineer in charge, at $200 per month	$200	
2 assistant engineers, at $100 per month	200	
2 assistant engineers, at $90 per month	180	
5 rodmen, at $40 per month	200	
6 laborers, at $30 per month	180	
		$960
Erecting triangulation stations:		
2 foremen, at $50 per month	100	
2 recorders, at $40 per month	80	
4 laborers, at $30 per month	120	
		300
Steamer:		
1 pilot, at $150 per month	150	
1 steward and clerk, at $100 per month	100	
1 engineer, at $100 per month	100	
1 mate, at $60 per month	60	
1 carpenter, at $60 per month	60	
1 watchman, at $45 per month	45	
1 fireman, at $40 per month	40	
4 deckhands, at $30 per month	120	
1 cook, at $50 per month	50	
1 cook, at $30 per month	30	
1 waiter, at 30 per month	30	
2 waiters, at $25 per month	50	
1 laundress, at $20 per month	20	
		855
Fuel for steamer (estimated)		120
Subsistence		630
Total		$2,865

The last report received from this party, that for the week ending November 22 shows three lines of bench-marks established, and several observing stations repaired for the use of the triangulation parties.

It is not expected the number of bench-marks in any line will exceed four; of those already reported two lines have three each and the other only two.

The bench-marks are furnished at the price paid by the Mississippi River Commission.

The secondary triangulation parties did not get into the field until the 17th of November, as a suitable man to take charge of the work was not obtained until November 12, when Mr. O. B. Wheeler, late of the United States Lake Survey, reported for that duty.

The organization and pay of these parties are as follows, viz:

1 assistant engineer, in charge, at $220 per month	$220 00
1 assistant engineer, at $162.50 per month	162 50
1 assistant engineer, at $137.50 per month	137 50
2 rodmen, at $70 per month	140 00
1 rodman, at $57.50 per month	57 50
2 teamsters each, with horse, at $75 per month	150 00
	$867 50

The assistant in charge has general supervision of the work, and, with the junior rodman to assist him, locates his stations in advance of the party on the steamer that the latter may erect them without delay. On each bank is an observing party, consisting of an observer, a rodman, and a teamster, who occupy the stations on their own side of the river and communicate with the opposite party by signals.

The two fine Troughton & Simms instruments, used by these parties belong to and are kindly loaned by the Mississippi River Commission, as are the steel tape for measuring base-line and the observing tents.

In order to take proper care of the expensive borrowed instruments, two covered, spring, single wagons were purchased at a cost of $181, delivered at Glasgow, Mo.

The other instruments were furnished from those on hand.

As triangulation stations had been located and built from Glasgow, Mo., down to Boonville, Mo., before the organization of the Missouri River Commission, the former was selected as the point of beginning for both triangulation and bench-mark work.

Very respectfully, your obedient servant,

W. L. Fisk,
Lieutenant of Engineers,
Secretary Missouri River Commission.

Maj. Chas. R. Suter,
Corps of Engineers, U. S. A.,
President Missouri River Commission.

Appendix B.

United States Engineer Office,
Saint Louis, Mo., October 30, 1884.

Sir: I have the honor to report that in compliance with the resolution of the Missouri River Commission, adopted October 7, 1884, instructing me "to examine the bridge at Boonville, in response to the letter of William Young, dated September 22, and report the condition of the same to the president of the Commission as soon as possible for immediate action," I went to Boonville on the 24th instant.

Previous to going a copy of the resolution was sent to Mr. Hoxie, third vice-president of the Missouri Pacific Railroad, and the time decided upon for making the inspection was mentioned, to enable the railroad company to have a representative present.

A very prompt reply was received, stating that Mr. R. M. Peck, superintendent of bridges and buildings, would meet me there.

Mr. Peck went up on the same train with me, and explained that the work complained of must be the false works erected under the south span to enable them to complete the rebuilding of the bridge, the other spans having already been rebuilt without complaint.

The false works consist of trestles of cypress piling, resting on the rock bottom of the river, and placed at intervals of about 12 feet under each floor-girder.

At the north end of the span they started to throw in rock to secure the bottoms of the trestles from being moved by drift, but stopped after putting in one car-load. The depth of water at this place was said to be 25 to 27 feet, the gauge reading at the time about 8 feet.

I endeavored to see Mr. Young, but as he was several miles from home, at the house of a relative, was unable to do so.

I saw Captain Porter, owner of the ferry at Boonville, but he did not know any complaint had been made, nor had he heard any one ever suggest that the work at the bridge would have any injurious effect upon navigation or the harbor there, and referred me to Captain McPherson, who, as the only man in Boonville owning boats running up and down the river, was most interested. The latter expressed surprise that complaint had been made, and corroborated Captain Porter's statements, adding that Mr. Young had been on the river very little of late and then only on his (Captain McPherson's) boats.

Mr. Peck states that the piling will be entirely removed when they finish work on the bridge, probably within the next two weeks. Mr. Young's complaint, I think, must have been due to a misapprehension of the railroad company's work.

I returned to the city on the 25th instant.

Very respectfully, your obedient servant,

W. L. FISK,
First Lieutenant of Engineers, Secretary Missouri River Commission.

Maj. CHARLES R. SUTER,
Corps of Engineers, U. S. A., President Missouri River Commission.

APPENDIX C.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., December 9, 1884.

SIR: I have the honor to inclose herewith itemized statements of expenditures to December 1, 1884, under the various allotments made by the Commission, and assigned to me for disbursement.

Very respectfully, your obedient servant,

W. L. FISK,
First Lieutenant Engineers, Secretary Missouri River Commission.

Maj. CHAS. R. SUTER,
Corps of Engineers, U. S. A., President Missouri River Commission.

Allotment for care of plant below Sioux City, Iowa, preservation and observation of gauges and collection and compilation of physical data.

[Itemized statement of expenditures to November 30, 1884, inclusive.]

	Unpaid.
Pay-rolls	$3,422 49
Supplies	191 24
Gauges	85 00
Liabilities to be turned over by Major Suter, estimated	1,077 59
Total	$4,776 32

SUMMARY.

Total allotment	$25,000 00
Expenditures to November 30, 1884, inclusive	4,776 32
Balance December 1, 1884	$20,223 68

Allotment for office expenses, traveling expenses, and salaries of Commission.

[Itemized statement of expenditures to November 30, 1884, inclusive.]

Subjects of expenditure.	Paid.	Unpaid.	Total.
Salaries	$1,055 56	$416 66	$1,472 22
Office furniture	75 50	121 75	197 25
Gas-fixtures		89 70	89 70
Traveling expenses and mileage	353 28	186 55	539 83
Stationery	62 70	241 34	304 04
Fuel	31 46		31 46
Telegrams	1 13	85	1 98
Total	1,579 63	1,056 85	2,636 48

SUMMARY.

Total allotment	$20,000 00
Cash deposit, sale of fuel to officers	15 00
Total	20,015 00
Expenditures to November 30, 1884, inclusive	2,636 48
Balance December 1, 1884	$17,378 52

Allotment for additional surveys and establishment of permanent bench-marks below Sioux City.

[Itemized statement of expenditures to November 30, 1884, inclusive.]

Subjects of expenditure.	Paid.	Unpaid.	Total.
Pay-rolls	$2,161 23	$2,080 91	$4,242 14
Subsistence stores	862 11	160 10	1,022 21
Outfit of parties	252 28	....	252 28
Outfit of steamer Missouri	11 47	....	11 47
Medical supplies	12 15	....	12 15
Other supplies	46 39	65 07	111 46
Bench-marks and stations	57 90	550 70	608 60
Material for repair of steamer	439 74	....	439 74
Repairs of instruments	6 25	....	6 25
Transportation of instruments	....	18 85	18 85
Stationery	26 00	....	26 00
Traveling expenses	162 75	30 30	193 05
Total	4,038 22	2,905 93	6,944 15

SUMMARY.

Total allotment	$25,000 00
Expenditures to November 30, 1884, inclusive	6,944 15
Balance December 1, 1884	$18,055 85

Allotment for purchase of a tow-boat.

[Itemized statement of expenditures to November 30, 1884, inclusive.]

Total allotment	$25,000 00
Expenditures to November 30, 1884, inclusive	0 00
Balance December 1, 1884	$25,000 00

X X 2.

REPORT FOR 1885.

MISSOURI RIVER COMMISSION,
Saint Louis, Mo., October 13, 1885.

SIR: The Missouri River Commission have the honor to submit herewith their annual report for the fiscal year ending June 30, 1885.

The last annual report of the Commission, dated December 9, 1884, detailed the action of the Commission and the expenditures under their direction to December 1, 1884. The report also defined the preliminary recommendations of the Commission, the plans adopted for the improvement of the river, and the operations contemplated for the current season.

These may be briefly recapitulated as follows:

(1) For the upper river, viz, between Fort Benton and Sioux City: To continue on the rocky portion of the river, that is, above Carroll, the construction of wing-dams and dredging of shoals, while below Carroll operations were to be limited to snagging and some experimental dams to be built near Bismarck.

(2) For the lower river, viz, between Sioux City and the mouth: To extend certain works of protection already in position near Saint Joseph, Mo., and to begin near Kansas City the systematic improvement

of the river which is designed to progress continuously down-stream, the object sought being to establish a stable regimen with approximate uniformity of width, depth, and slope.

(3) To execute further surveys on the upper portion of the river, to extend a system of triangulation over the lower portion, and to establish permanent bench-marks for future reference, and to connect with surveys already made.

(4) The Commission recommended, to carry on the works thus outlined, that the following appropriations be made:

Appropriation for the improvement of Missouri River from its mouth to Sioux City	$1,000,000
Appropriation for the improvement of Missouri River from Sioux City to Fort Benton	160,000
Reappropriation for the survey of the Missouri River from its mouth to its headwaters of the item of $15,000 appropriated in the act of July 5, 1884, for survey of river above the Falls	15,000
Appropriation for survey, examinations, and investigations, and for traveling and office expenses, and salaries of the Commission, with the suggestion that this item be attached to the sundry civil bill, as in the case of the Mississippi River Commission	150,000

From the appropriations under their control, the Commission made allotments, which were approved by the Secretary of War, as follows:

LIST OF ALLOTMENTS.

From appropriation for improving Missouri River from its mouth to Sioux City, Iowa, act of July 5, 1884		$500,000 00
For office expenses, traveling expenses, and salaries of Commission	$20,000 00	
For additional surveys and establishment of permanent bench-marks below Sioux City	25,000 00	
For care of plant, preservation and observation of gauges, and collection and compilation of physical data	25,000 00	
For purchase of tow-boat	25,000 00	
For improving Missouri River in the vicinity of Kansas City, Mo	300,000 00	
For improving Missouri River in the vicinity of Saint Joseph, Mo	105,000 00	
		500,000 00
From appropriation for improving Missouri River from Sioux City, Iowa, to Fort Benton, Mont., act of July 5, 1884		125,000 00
For office expenses and expenses of Commission	$5,000 00	
For surveys between Fort Benton, Mont., and Sioux City, Iowa	25,000 00	
For office and inspection expenses of district officer	6,500 00	
For work below Fort Benton, Mont	30,000 00	
For purchase and repair of plant	58,500 00	
		125,000 00
From appropriation for improving Missouri River from Sioux City, Iowa, to Fort Benton, Mont., act of August 2, 1882, unexpended balance December 1, 1884		4,000 00
For office and inspection expenses of district officer	$2,000 00	
For purchase and repair of plant	2,000 00	
		4,000 00
From appropriation for survey of Missouri River from its mouth to Fort Benton, Mont., act of August 2, 1882, unexpended balance December 1, 1884		8,844 39

Owing to the late date at which these preliminary matters were settled, the Commission judged it expedient to suspend the commencement of the field work of improvement till after the resumption of navigation in the spring of 1885, and, until that period, all operations under this

head were confined to caring for public property and the construction and repair of plant. Surveying parties were kept in the field all winter, and at the office of the Commission work was in progress on the compilation and reduction of physical data already on hand.

SURVEYS.

A general survey of the river had been in progress for several years before the organization of the Commission, and had reached Fort Pierre, Dak., 1,174 miles from the mouth of the river. This survey, though excellent in character, had, owing to insufficient means, been carried on without leaving a sufficient number of durable monuments which would enable comparisons to be made with its maps in future years. To remedy this deficiency it was decided to extend a system of secondary triangulation along the river valley, the stations being located on the bluffs and permanently marked. In addition to this, lines of permanent bench-marks are to be located across the valley at intervals of about 5 miles, their direction being as nearly as possible normal to the stream. These lines are connected with the triangulation stations, and are also located accurately on the maps of the existing survey. Their elevation is also determined by connection with the established line of levels. It is expected that a sufficient number of durable reference-points will thus be furnished to enable future surveys to be connected without trouble with the work done heretofore.

The work of locating these bench-marks was begun at Glasgow, Mo., November 12, 1884, and ended December 15, at Boonville, Mo., a distance of 30 miles having been covered, and eight lines of reference stones having been placed and located.

The triangulation began at the same date at Glasgow, Mo., and was kept up all winter. On May 13 it had progressed down-stream 176 miles to Tavern Rock, 50 miles from the mouth of the river, where it closed on a station of the Coast Survey.

In the spring preparations were made for carrying on the survey of the upper river, which, on account of the necessity for early information, it was decided to commence at Fort Benton and carry down to a junction with the work already done below Fort Pierre. Owing to the failure of the river and harbor bill it was found impossible, with the funds available, to make this survey as complete or extensive as originally intended. It is designed this year to carry on the triangulation, levels, and bench-mark location, all of which work is preliminary, leaving the topography and hydrography to be supplied in the future. The party organized for this purpose was collected at Bismarck, Dak., June 1, and at the date of June 30 were still on the way to Fort Benton. They were expected to begin work about July 5, and to remain in the field until October 1. The total distance from Fort Benton to Fort Pierre is about 1,068 miles, and 230 miles will probably be covered this season. During the year seventeen gauges have been kept up on the river and their readings recorded.

Work in the office has been mainly devoted to the compilation and reduction of physical data, of which a large amount was on hand, but not available for study. (For further details see Appendices A, A 1, and A 2.)

FIRST DISTRICT.

MOUTH OF RIVER TO SIOUX CITY.

In the early part of the winter the plant pertaining to this work was collected for safe-keeping at Saint Joseph, Mo., Kansas City, Mo., and

at Bushberg, near Saint Louis, under the direction of the secretary of the Commission, and fifteen additional barges, 100 by 25 feet, were ordered for the work. January 21, the Secretary of War directed that Maj. Chas. R. Suter, Corps of Engineers, U. S. A., be assigned to the charge of this work, with headquarters at Saint Louis. During the winter preparations were made for beginning work as soon as navigation was safe from interruption by ice. In March, at Saint Joseph and Kansas City, repairs were begun to the plant stored at those places, and in April the moving of the new plant from Bushberg to Kansas City and Saint Joseph was begun. This latter work consumed much time. Three tow-boats were continuously employed till the end of June, and the last tow reached the works late in July. A total of eighty-one pieces was sent up the river in eighteen tows. Up to the end of June only the old plant was available for work.

The field work of improvement has been carried on near Saint Joseph and Kansas City.

At the former place the Commission decided to repair the revetment constructed in previous years on the right bank of the river, near Elwood, Kans., and opposite Saint Joseph; and also to revet the left bank of Bonton Bend, in order to prevent a threatened cut-off through French Bottom.

Work was begun in April on the breaks in the Elwood revetment, and an aggregate of 940 feet of woven willow mattress was constructed and sunk. Work was then begun on the Bonton Revetment, and prosecuted until temporarily suspended June 12, owing to the high stage of the river, after 776 feet of mattress had been constructed and sunk. During the balance of the season it is intended to extend this revetment about 10,000 feet, which is all the available funds will justify.

At Kansas City, which the Commission have selected as the initial point of the general improvement of the river, it was decided to revet the caving banks in Parkville, Quindaro, and Kaw bends, as a preliminary to extending the work down the river. The failure of the river and harbor bill will prevent the completion even of these preliminary works during the present season. As early as possible the plant at Kansas City was got in readiness, and work was begun April 17 at the upper end of Kaw Bend. Work was prosecuted under many difficulties, but by the end of June a length of 3,000 feet of caving bank had been revetted. During the remainder of the season it is expected that the work will progress much more rapidly, the new plant being available, and by November the revetments in Kaw and Quindaro bends will probably be completed, and the funds at the disposal of the Commission exhausted.

For details of the work of construction the Commission beg to refer to the reports of the district officer and his assistants.

(Appendices B, B_1, B_2, B_3.)

SECOND DISTRICT.

SIOUX CITY TO FORT BENTON.

This work has been in charge of Capt. James B. Quinn, Corps of Engineers, U. S. A., with headquarters at Saint Paul, Minn.

Work in this district prior to June 30 has been limited to preparations for work during the coming season. The steamer Josephine was

purchased and fitted up as a snag-boat, and a dredge and five barges are being constructed. The steamer Emily, belonging to the work, was sunk by ice at Bismarck last winter. During the coming season work will be confined to repair and construction of dams and the dredging of shoals on the rocky portion of the river. For details, see report of district officer (Appendix C).

RECOMMENDATIONS.

The plan of improvement adopted by the Commission for the lower portion of the river contemplates a reduction of width of water-way sufficient to insure stability of regimen and approximate uniformity of slope, width, and depth. The Commission are satisfied of the engineering feasibility of this improvement and of the great benefits likely to follow its completion, but they are not prepared to estimate its cost. To do so they are of the opinion that the experiment should be tried on an extensive scale and with ample means, so as to cover a considerable length of river and insure the completion of any work undertaken. They consider that for this purpose annual appropriations of not less than $1,000,000 should be made.

For the upper river the Commission recommend that, for the present, work be mainly confined to the construction of dams and dredging of shoals on the "rocky river" above Carroll. Below that point the snag-boat should be kept at work removing obstructions, and funds should be provided therefor. For these purposes and for certain experimental dams to be constructed near Bismarck the Commission recommend an appropriation of $160,000.

For continuing the survey of the river and for obtaining the data necessary for a proper study of the important interests committed to their charge, the Commission recommend that a separate appropriation be made, which shall also provide for the salaries of the commissioners and for office and traveling expenses. For this purpose the sum of $150,000 is recommended, with the suggestion that it be attached to the sundry civil bill, as has heretofore been done in the case of the Mississippi River Commission.

In the last river and harbor bill an item of $15,000 was appropriated for a survey of the Missouri River above Fort Benton. As the Commission have not been able to ascertain that any present necessity exists for such a survey, they have taken no steps to expend the money, and they respectfully renew their recommendation of last year that it be re-appropriated and made available for the survey of the river below Fort Benton.

The recommendations of the Commission for the year ending June 30, 1887, are recapitulated as follows:

(1) Appropriation for the improvement of Missouri River from its mouth to Sioux City	$1,000,000
(2) Appropriation for the improvement of Missouri River from Sioux City to Fort Benton	160,000
(3) Reappropriation for the survey of the Missouri River from its mouth to its headwaters of the item of $15,000, appropriated in the act of July 5, 1884, for survey of river above the Falls	15,000
(4) Appropriation for survey, examinations, and investigations, and for traveling and office expenses, and salaries of the Commission, with the suggestion that this item be attached to the sundry civil bill, as in the case of the Mississippi River Commission	150,000

MONEY STATEMENT.

Available December 1, 1884, and received since to June 30, 1885:			
Appropriation for survey of Missouri River from its mouth to Fort Benton, Mont., act of August 2, 1882			8,844 39
Appropriation for improving Missouri River from Sioux City, Iowa, to Fort Benton, Mont., act of August 2, 1882			4,000 00
Appropriation for improving Missouri River from its mouth to Sioux City, Iowa, act of July 5, 1884			485,658 05
Appropriation for improving Missouri River from Sioux City, Iowa, to Fort Benton, Mont., act of July 5, 1884			125,000 00
Appropriation for survey of the Missouri River above Missouri River Falls at Fort Benton, act of July 5, 1884			15,000 00
From sales of fuel to officers			112 10
Total			638,614 54
Expended from December 1, 1884, to June 30, 1885, exclusive of outstanding liabilities December 1, 1884:			
By first district officer		$65,461 53	
By second district officer		55,041 79	
By the secretary of the Commission		71,962 83	
		192,466 15	
Outstanding liabilities July 1, 1885:			
Of first district officer	$16,861 60		
Of second district officer	9,928 74		
Of the secretary of the Commission	4,165 88		
		30,956 22	
			223,422 37
Balance available July 1, 1885			$415,192 17

Respectfully submitted,

CHAS. R. SUTER,
Major of Engineers,
President Missouri River Commission.
A. MACKENZIE,
Major of Engineers.
O. H. ERNST,
Major of Engineers.
G. C. BROADHEAD.
WILLIAM J. BROATCH.

The Hon. SECRETARY OF WAR.
(Through the Chief of Engineers. U. S. A.)

Financial statement December 1, 1884, *to June* 30, 1885.

Work.	Resources.				Expenditures.				
	Balance appropriated by act of August 2, 1882, on hand December 1, 1884.	Appropriations by act of July 5, 1884.		Received, sales of fuel to officers.	To December 1, 1884 (last report).	Since December 1, 1884.		Total to June 30, 1885.	Unexpended balances June 30, 1885.
		Allotted.	Unallotted.			Paid.	Unpaid liabilities.		
FROM ITS MOUTH TO SIOUX CITY, IOWA.									
In charge of Secretary.									
Survey of Missouri River from its mouth to Fort Benton, Mont.	$8,844 39					$344 39		$344 39	$8,500 00
Office and traveling expenses, and salaries of Commission		$20,000 00		$127 10	$1,579 63	$8,945 43	$197 85	10,722 91	9,404 19
Surveys and permanent bench-marks		25,000 00			4,038 22	19,312 71	323 07	23,674 00	1,326 00
Care of plant, river gauges, physical data		25,000 00				14,503 42	60 00	14,563 42	10,436 58
Tow-boat		25,000 00				850 00		850 00	24,150 00
Fifteen barges		27,064 84				27,064 84		27,064 84	
In charge of Major Suter, Corps of Engineers.									
Kansas City		279,951 96				42,853 30	12,276 89	55,130 19	224,821 77
Saint Joseph		97,983 20				22,608 23	4,584 71	27,192 94	70,790 26
FROM SIOUX CITY TO FORT BENTON, MONTANA.									
In charge of Captain Quinn, Corps of Engineers.									
Office and inspection expenses, district officer	2,000 00	6,500 00				2,371 69	343 39	2,715 08	5,784 92
Work below Fort Benton		30,000 00				7,326 79	2,500 00	9,826 79	20,173 21
Purchase and repair of plant	2,000 00	58,500 00				45,343 31	7,085 35	52,428 66	8,071 34
In charge of Secretary.									
Office and Commission expenses		5,000 00							5,000 00
Surveys		25,000 00				9,681 14	3,584 96	13,266 10	11,733 90
ABOVE FORT BENTON.									
Survey above Falls			$15,000 00						15,000 00
Totals	12,844 39	625,000 00	15,000 00	127 10	5,617 85	201,205 25	30,956 22	237,779 82	415,192 17

Respectfully submitted,

THEO. A. BINGHAM,
First Lieut. of Engineers, Secretary Missouri River Commission.

APPENDIX A.

ANNUAL REPORT OF THE SECRETARY OF THE COMMISSION.

MISSOURI RIVER COMMISSION,
Saint Louis, Mo., October 6, 1885.

MAJOR: I have the honor to submit annual report on work in charge of the secretary from December 1, 1884, to June 30, 1885, with itemized statements of expenditures and reports of assistant engineers.

Very respectfully, your obedient servant,

THEO. A. BINGHAM,
First Lieut. of Engineers,
Secretary Missouri River Commission.

Maj. CHAS. R. SUTER,
Corps of Engineers,
President Missouri River Commission.

ADDITIONAL SURVEYS AND ESTABLISHMENT OF PERMANENT BENCH-MARKS BELOW SIOUX CITY. (SECONDARY TRIANGULATION.)

Parties were in the field at the date of last report. The permanent bench-mark party remained out until December 15, when all were discharged except the assistant engineer in charge, who was retained to complete his office work.

The lines extend across the river valley at intervals of about 5 miles, and as nearly as possible normal to the thread of the stream. Not more than four bench-marks will probably be needed for any one line, and in the work done so far no line has more than three.

Work began at Glasgow, Mo., November 12, 1884, and ended at Boonville, Mo., December 15, a distance of 30 miles. The lines completed are numbered from 40 to 48, both inclusive, and contain twenty-four bench marks. The series begins at the mouth of the Missouri River. The notation used is, for instance, $\frac{48}{1}$, $\frac{48}{2}$, &c., the upper being the number of the line and the lower the number of the bench-mark in that line, beginning on the right bank.

One or more of the bench-marks in each line is connected with the secondary triangulation, and also with the previous survey.

Angles were taken to determine the azimuths of these lines for the final reduction of the notes.

The bench-marks used were almost identical with those described in the Annual Report of the Mississippi River Commission for 1883, page 164. Their cost, delivered in Saint Louis, was $1.75 apiece for the first 200, and $1.55 apiece for a subsequent 800. The pipes are 4 feet long and project from the ground 1 foot.

Levels were determined of all bench-marks except four, which were left for the future, to avoid delaying the main party. All levels were checked and rerun when a difference occurred exceeding one-hundredth of a foot.

The building of triangulation stations was continued until March 30, when connection was made with the primary work of the Coast Survey at Tavern Rock, Mo., about 50 miles above the mouth of the river.

Distance, Glasgow to Tavern Rock, about 176 miles.

These stations are similar to the bench-marks, except that the pipe is 3 feet long. The triangulation party was out all winter, and by the 13th of May had closed with the Coast Survey at Tavern Rock, Mo., distant from Glasgow, Mo., about 176 miles. It was not found altogether satisfactory to carry on such work during the winter. Much time was lost by bad weather, stations had to be reoccupied often, &c.

The results have still to be worked up, and a special report will then be made. The party after finishing this field work went immediately to the Upper Missouri River.

SURVEYS BETWEEN FORT BENTON, MONTANA, AND SIOUX CITY, IOWA.

The steamer Missouri, after being fitted for her long trip, left Saint Louis April 13 with a few only of the proposed party, stores for fifty-seven men for five months, and as many bench-marks as she could carry. Arrived at Bismarck, Dak., June 1. Was here joined by the rest of the party and the remainder of the bench-marks. On the 30th of June was at Dauphin's Rapids, 95 miles below Fort Benton.

She had been much delayed by wind. It was expected that work would begin at Fort Benton by the 5th of July.

On the trip up, above Pierre, Dak., two assistants were constantly taking bearings and estimating distances. These results were mapped for use as the survey proceeds. The results agreed closely with previous ones accepted as good, and showed that there were very nearly 1,068 miles to be surveyed between Fort Benton and Pierre, Dak., the present upper limit of the surveyed portion of the river.

The party for the work is organized as follows (with monthly rate of pay):

PERMANENT BENCH-MARK PARTY.

Administration.

1 assistant engineer in charge	$200 00	
1 clerk and steward	100 00	
		$300 00

Setting and connecting permanent bench-marks.

1 assistant engineer	100 00	
2 rodmen, at $40	80 00	
1 foreman	50 00	
3 laborers, at $30	90 00	
		320 00

Leveling.

1 assistant engineer	125 00	
1 assistant engineer	90 00	
2 rodmen, at $40	80 00	
6 laborers, at $30	180 00	
		475 00

Building triangulation stations.

2 foremen, at $50	100 00	
4 laborers, at $30	120 00	
1 laborer, with horse	35 00	
		255 00

Transportation.

1 pilot	125 00	
1 engineer	100 00	
1 mate and pilot	90 00	
1 carpenter	50 00	
1 watchman	45 00	
1 fireman	40 00	
4 deck hands, at $30	120 00	
2 cooks, at $45	90 00	
3 waiters, at $26.66⅔	80 00	
1 laundress	15 00	
		755 00
Total per month		$2,105 00

TRIANGULATION PARTY.

1 assistant engineer in charge	175 00	
1 assistant engineer	125 00	
1 assistant engineer	100 00	
3 rodmen, at $40	120 00	
1 mate	40 00	
1 cook	30 00	
3 boatmen, at $30	90 00	
6 laborers, at $30	180 00	
Total		860 00
Grand total per month		2,965 00

CARE OF PLANT, PRESERVATION AND OBSERVATION OF GAUGES, AND COLLECTION AND COMPILATION OF PHYSICAL DATA.

Until January 21, 1885, the plant belonging to the Missouri River below Sioux City, was cared for and the funds disbursed by the secretary. Since that date the plant of the two districts has been in the hands of the engineer officers in charge.

Gauges have been read twice daily at seventeen stations on the river, whose locations are given in Mr. Seddon's report. It is intended to have all the gauges tested and corrected quarterly; but for lack of funds nothing has been done since January, when those marked by (*) were put in good order.

Weekly reports are rendered by observers; these are plotted and any irregularities are investigated and corrected.

At the end of the year the daily readings are filed on one sheet, which contains reference map and all data necessary to a complete record.

The daily reports of the Signal Service are regularly received.

Many of their gauge reports for previous years have also been obtained.

The records of this branch are in very good shape.

The work on physical data of the river has consisted of the compilation of a large quantity of notes. This compilation is necessary to get the notes in such shape that they can be studied.

The notes comprise mainly discharge observations. There are a few notes on borings, which are added to from time to time.

Much recalculation of original notes has been found necessary. It is impossible to give an exact report of the results accomplished thus far, but Mr. Seddon's report shows in detail the present state of the work. A noteworthy feature of the compilation is the graphic method of computing discharges.

PURCHASE OF TOW-BOAT.

The drawings have all been completed and blue printed. The specifications are drawn up and ready for the printer. A model of the hull has been made.

Nothing further has been done since May.

PURCHASE OF BARGES.

The drawings and specifications were completed in January, and bids called for. The contract was awarded to D. S. Barmore & Son, of Jeffersonville, Ind., the lowest bidders, at $1,775 apiece delivered at their yards.

They were finished and taken to the works at Kansas City, in May, by the Commission tow-boat, "Emma Etheridge."

Their size is 100 by 25 feet.

EXPENDITURES.

SURVEY OF THE MISSOURI RIVER FROM ITS MOUTH TO FORT BENTON, MONTANA.

[Act passed August 2, 1882.]

Balance available of above appropriation		$8,844 39
Expended to November 30, 1884, inclusive	$0 00	
Itemized expenditures from December 1, 1884, to June 30, 1885, both dates inclusive:		
Pay-roll	320 00	
Traveling expenses	19 39	
Repairs to steamboat	5 00	
	344 39	
Unpaid liabilities, June 30, 1885	0 00	
Total expenditures to June 30, 1885		344 39
Balance available, June 30, 1885		8,500 00

OFFICE EXPENSES, TRAVELING EXPENSES, AND SALARIES OF COMMISSION.

Total allotment			$20,000 00
Received from sales of fuel to officers			127 10
			20,127 10
Expended to November 30, 1884, inclusive		$1,579 63	
Itemized expenditures from December 1, 1884, to June 30, 1885, both dates inclusive:			
Office rent	$800 00		
Gas, water, &c	37 57		
Telephone	50 00		
Stationery	226 59		
Safe	425 00		
Office furniture	288 07		
Fuel	354 97		
Pay-rolls and salaries	5,973 53		
Traveling expenses and mileage	514 11		
Telegrams	2 82		
Repairs	138 98		
Sundries	133 79		
		8,945 43	
Unpaid liabilities, June 30, 1885		197 85	
Total expenditures to June 30, 1885			10,722 91
Balance available, June 30, 1885			$9,404 19

ADDITIONAL SURVEYS AND ESTABLISHMENT OF PERMANENT BENCH-MARKS BELOW SIOUX CITY.

Total allotment			$25,000 00
Expended to November 30, 1884, inclusive		$4,038 22	
Itemized expenditures from December 1, 1884, to June 30, 1885, both dates inclusive:			
Pay-rolls	$12,415 69		
Subsistence	225 65		
Outfit of parties	107 27		
Medical and other supplies	20 33		
Bench-marks and triangulation stations	5,887 06		
Repairs	190 43		
Transportation	73 21		
Traveling expenses	212 15		
Fuel	67 92		
Privilege felling trees	86 50		
Station markers	26 50		
		19,312 71	
Unpaid liabilities June 30, 1885		323 07	
Total expenditures to June 30, 1885			23,674 00
Balance available June 30, 1885			$1,326 00

CARE OF PLANT, PRESERVATION, AND OBSERVATION OF GAUGES, AND COLLECTION AND COMPILATION OF PHYSICAL DATA.

Total allotment		$25,000 00
Expended to November 30, 1884, inclusive	$0 00	
Itemized expenditures from December 1, 1884, to June 30, 1885, both dates inclusive:		
Pay-rolls	$12,702 03	
Subsistence	415 77	
Piles	178 40	
Lumber	561 88	
Oakum	42 50	
Pitch	28 00	
Tacks and cotton	10 30	
Hand grenades	71 73	
Engineers and stewards' supplies	88 63	
Transportation	57 01	
Traveling expenses	87 15	
Stationery	164 00	
Storehouse	35 00	
Dynamite	20 00	
Fuel	41 02	
	14,503 42	
Unpaid liabilities June 30, 1885	60 00	
Total expenditures to June 30, 1885		14,563 42
Balance available June 30, 1885		$10,436 58

PURCHASE OF TOW-BOAT.

Total allotment		$25,000 00
Expended to November 30, 1884, inclusive	0 00	
Itemized expenditures from December 1, 1884, to June 30, 1885, both dates inclusive:		
Draughtsman	$850 00	
Unpaid liabilities, June 30, 1885	0 00	
Total expenditures to June 30, 1885		850 00
Balance available June 30, 1885		$24,150 00

PURCHASE OF BARGES.

Total allotment		$27,064 84
Expended to November 30, 1884, inclusive	0 00	
Itemized expenditures from December 1, 1884, to June 30, 1885, both dates inclusive:		
Inspection	$433 34	
Barges	26,625 00	
Traveling expenses	6 50	
	27,064 84	
Unpaid liabilities June 30, 1885	0 00	
Total expenditures to June 30, 1885		27,064 84
Balance available June 30, 1885		0 00

OFFICE EXPENSES AND EXPENSES OF COMMISSION.

[Sioux City, Iowa, to Fort Benton, Montana.]

Total allotment	$5,000 00
Itemized expenditures from December 1, 1884, to June 30, 1885, both dates inclusive	0 00
Balance available June 30, 1885	5,000 00

SURVEYS BETWEEN FORT BENTON, MONTANA, AND SIOUX CITY, IOWA.

Total allotment		$25,000 00
Expended to November 30, 1884, inclusive	0 00	
Itemized expenditures from December 1, 1884, to June 30, 1885, both dates inclusive:		
Pay-rolls	$2,401 99	
Subsistence	2,628 14	
Traveling expenses	2 00	
Repairs to steamer Missouri	2,744 26	
Supplies	765 97	
Fuel	720 78	
Repairs to chronometer	7 50	
Bench-marks	312 50	
Portable tripods	98 00	
	9,681 14	
Unpaid liabilities June 30, 1885	3,584 96	
Total expenditures to June 30, 1885		13,266 10
Balance available June 30, 1885		$11,733 90

Respectfully submitted,

THEO. A. BINGHAM,
First Lieut. of Engineers,
Secretary Missouri River Commission.

To Maj. CHAS. R. SUTER,
Corps of Engineers, President of Commission.

A 1.

REPORT OF MR. JAMES A. SEDDON, ASSISTANT ENGINEER.

MISSOURI RIVER COMMISSION,
Saint Louis, Mo., October 6, 1885.

SIR: I have the honor to make the following report of the physical data department to June 30, 1885.

The physical data work comprises two distinct divisions:

I. The compilation of the data, or the putting in uniform or available shape all the measurements that have been made of the physical properties of the river.

II. The study of the data, or the study of these properties in regard to the relations that exist between them, and deductions from these relations. The work will be considered in this order.

I.—THE COMPILATION OF THE DATA.

Considering first the condition of the work. The compilation of the data contemplates their collection and filing in five volumes, corresponding to five divisions of the river, which divisions are given as follows, by those local charges included in them at which data have been collected.

Volume I.—Saint Charles and Cedar City.
II.—Boonville and Glasgow.
III.—Lexington, Kansas City, and Leavenworth, or Kansas City Division.
IV.—Atchison and Saint Joseph, or Saint Joseph Division.
V.—Brownville, Nebraska City, Plattsmouth, Omaha, Sioux City, and Vermillion.

The condition of the compilation for these volumes or divisions will be given in the following table, the data being considered under the heads of "Cross-sections," "Slope," "Discharge," "Borings," "Miscellaneous."

As gauge data are more extended than the local charges and are completed for the river with the exception of the final compilation of histories, they have been omitted from the table.

Under the head of "Miscellaneous," all data that are not comprised in the other divisions are included, such as valley profiles, ground water, erosion, &c. There are not many data under this head unless it is decided to make a thorough compilation of erosion, in which case it would require much work.

It is thought, however, that this had best wait the study of the other data.

As yet no work has been done on the compilation of miscellaneous data.

No. of volume.	Local charges at which data were collected.	Cross-sections.	Slope.	Discharged.	Borings.	Miscellaneous.	Remarks.
I.	Saint Charles	C	C	¾C	½C	O	
	Cedar City	C	X	X	X	O	
II.	Boonville	C	C	X	X	X	No data except low-water survey, of 1882.
	Glasgow	C	O	X	X	O	
III.	Lexington	¾C	C	X	X	O	
	Kansas City	¾C	¾C	½C	X	O	
	Leavenworth	¾C	C	X	X	O	
IV.	Atchison	C	C	C	X	O	Only a few discharges.
	Saint Joseph	C	C	C	X	O	
V.	Brownville	O	O	X	X	O	
	Nebraska City	C	C	½C	C	O	
	Plattsmouth	O	O	X	C	O	
	Omaha	½C	O	O	O	O	
	Sioux City	O	O	O	O	O	
	Vermillion	X	X	X	X	O	Very few data here.

ABBREVIATIONS USED IN TABLE.—C is "Completed," and the degree of completion is given as a fraction of C. O is "No work done on the compilation." X is "Few if any data of the kind at the point."

As a general summary, a necessarily rough approximation would place the compilation of the data as a little over three-quarters completed.

The work done on this compilation since December 1, 1884, will be considered in detail under the heads of "Gauges," "Cross-sections and slope," "Discharge," "Borings," and "Other work."

GAUGES.

All the gauge readings taken on the Missouri River have been reduced to elevations above the Saint Louis Directrix. These have been compiled on "yearly gauge sheets," and from these yearly sheets the mean daily readings have been made. To complete the work, histories will have to be compiled for each point where gauge readings were taken, giving the changes of zero and location of gauge and character of the readings. This is in progress.

The following is a statement:

Regular.

Place at which gauge was read.	Readings reduced, yearly and mean sheet compiled.	
	Number of years.	Years for which compiled.
Saint Charles	7	1878 to 1884
Hermann*	12	1873 to 1884
Jefferson and Cedar City	7	1878 to 1884
Boonville	12	1873 to 1884
Glasgow	7	1878 to 1884
De Witt	2	1883 to 1884
Waverly	4	1878 to 1879 1883 to 1884
Lexington	12	1873 to 1884
Kansas City	12	1873 to 1884
Leavenworth*	12	1873 to 1884
Fort Leavenworth	10	1872 to 1881
Atchison*	7	1878 to 1884
Saint Joseph	13	1872 to 1884
White Cloud	4	1881 to 1884
Brownville*	5	1880 to 1884
Nebraska City	7	1878 to 1884
Plattsmouth*	12	1873 to 1884
Omaha*	13	1872 to 1884
Vermillion	4	1879 to 1882
Sioux City*	7	1878 to 1884

* Repaired in January, 1885.

Miscellaneous.

Jamestown Landing	2	1878 and 1879
Cottleville Landing	2	1878 and 1879
Washington	2	1878 and 1879
Fisher's Landing	2	1878 and 1879
Providence	2	1878 and 1879
New Frankfort	2	1878 and 1879
Miami	2	1878 and 1879
Camden	2	1878 and 1879
Missouri City	2	1878 and 1879
Blair	2	1880 and 1881
Decatur	2	1880 and 1881
Running Water	1	1881
Fort Randall	2	1881 and 1882
Bijou Hills	1	1882
Chamberlain	1	1882
Fort Pierre	1	1882

Of this work the readings had been reduced and "yearly gauge sheets" compiled prior to December 1, 1884, for thirty of these years. Hence, for recapitulation of work done on gauge data since December 1, 1884.

Gauge readings reduced and yearly gauge sheets compiled for 167 years.

Sheets of mean daily gauge readings compiled for 197 years.

CROSS-SECTIONS AND SLOPE.

The compilation of cross-section data consists in plotting all the cross-sections that have been taken on the Missouri River on standard section paper to a scale that gives at any time the value of any element to about the accuracy of its original measurement. The areas of these sections are then measured and a tabulation made of the elements of the sections, such as gauge, area, width, mean depth, &c. With the cross-sections reference maps are also made showing the location of the ranges on which the cross-sections were taken. Thus the sheets of cross-sections, with their accompanying reference maps and tabulations, make up the complete record of cross-section data. The compilation of slope data is as follows: Where practicable, the cross-sections are spaced channel distance apart, and on the sheets of cross-sections the slope profile is plotted to a suitable scale. Where this cannot be done, special slope-profiles are made. Reference maps, showing the location of points where slope

was taken, with tabulations of elements, complete the slope record. The following is a statement of work done under this head since December 1, 1884:

Complete:

Saint Charles:

423 cross-sections plotted; areas measured; reference maps and tabulations made.

104 miles of slope plotted; reference maps and tabulations made.

Cedar City:

77 cross-sections plotted; areas measured; reference maps and tabulations made; no slope found.

Glasgow:

108 cross-sections plotted; areas measured; reference maps and tabulations made.

37 miles slope plotted; reference maps and tabulations made.

Incomplete:

The following cross-sections require the measurement of areas and tabulations of elements to complete the record:

Omaha:

133 cross-sections plotted; reference maps made.

The following sections have been plotted to standard scale on manila paper. They require to be traced on standard section paper, the areas measured, and the tabulations made, to complete the record.

Lexington:

238 cross-sections, with reference maps.

Kansas City:

306 cross-sections, with reference maps.

Leavenworth:

16 cross-sections of 1884, with reference maps.

All the section and slope data taken at Leavenworth prior to 1884 were received in shape for filing.

Recapitulation:

Cross-sections:

608 cross-sections completed.

133 cross-sections incomplete, wanting areas and tabulations.

560 cross-sections incomplete, wanting tracing areas and tabulations.

Slope:

141 miles slope completed.

DISCHARGES.

The compilation of these data consists in the computation of all the discharges that have been taken on the river by the graphic method, and the filing of these, plotted on section paper to a suitable scale, with reference maps showing the location of the discharge ranges and with tabulations of the elements.

The graphic method has been taken for two reasons: First, because it gives the most accurate determinations of the discharge; second, because it admits of showing on a diagram both the observations and the computations. It consists of plotting from the water-line of the middle section the three curves—cross-section, normal velocity, and "elements of discharge." The ordinates of the last curve are the products of depth and velocity at every point where velocity is observed, and at pronounced points of flexure in the cross-section. The area of this curve gives the discharge.

These three curves, with the upper and lower cross-section when sounded, and the path of floats through the discharge-ranges, constitute the graphic record of a discharge, and with reference maps and tabulations, the record of a series of observations. They are plotted on section-paper to a scale that will give any value fully within the accuracy of its original observation, and furnish not only a record of the measurements, but a ready means of estimating the value in accuracy of determination of the discharge observations as a whole.

A variety of methods have been used in the first computations of the discharges taken on the Missouri River, and for obtaining similarity in results and a standard record under the above plan of compilation a considerable amount of work is required.

The work done on this has been as follows:

Saint Charles, (discharges of 1879):

This series embraced discharge observations from February 6 to October 28, or 168 observations in all, which is by far the largest series that has been taken on the river. They were calculated by the method of partial areas, using instead of normal velocities the velocity on the line of floats. They required entire recomputation. This recomputation has been completed, and all values for the tabulation have been deduced. To complete the compilation these will have to be traced on section paper, with path of floats, for file record.

BORINGS.

The following is a statement of work done on borings:

Nebraska City:

38 borings put in shape for filing with accompanying reference map.
1 valley cross-section showing strata with accompanying reference map.

Plattsmouth:

1 partial valley section showing bed rock at three points, with accompanying reference map.

Saint Charles:

3 valley sections showing strata. Reference maps to be made.

OTHER WORK.

Low-water survey, fall of 1882, from Charleston to Boonville.

The data of this survey was received in the Saint Louis office very nearly in shape. The work done on it in this office is as follows:

Four maps extending from Lexington to Boonville were reduced to scale of 2 feet = 1 inch and tracings have been made of two of these maps.

II.—THE STUDY OF THE DATA.

No work has been done on this part since December 1, 1884.

In considering the condition of this part of the work, the study of relations has been chiefly confined to the relations existing between discharge and gauge heights. Some fragmentary study of cross-sections and other relations has been attempted, but has not as yet proved fruitful.

The general directions of the study comprise, first, the revision of the discharge gauge relations, when the discharge data has been gotten in final shape, and from these relations, with the relations existing between gauges at different points, the deduction of the variation of discharge from point to point down the river, and from day to day during the time that is covered by gauge readings, or, in other words, the fullest attainable knowledge of the river as regards its volume; second, from the study of cross-section and slope data in the light of the above knowledge, the attainment of a more or less fragmentary knowledge of the changes of bed answering to these changes of volume.

Further than this the direction of study cannot be forecast.

Very respectfully, your obedient servant,

JAMES A. SEDDON,
Assistant Engineer.

First Lieut. T. A. BINGHAM,
Corps of Engineers,
Secretary of Missouri River Commission.

A 2.

REPORT OF MR. D. W. WELLMAN, ASSISTANT ENGINEER.

IMPROVEMENT OF THE MISSOURI RIVER,
UNITED STATES STEAMER MISSOURI,
Fort Benton, Mont., July 6, 1885.

SIR: I have the honor to submit herewith the following report relating to the portion under my charge of the survey of the Missouri River for the year ending June 30, 1885.

The Missouri River work having been placed by the last Congress in the hands of a

commission, a brief history of the progress of the survey from the beginning may not be inappropriate. This work was begun September 1, 1878, at the town of Weston, a short distance above Fort Leavenworth, under an appropriation of $50,000 for a survey of the river from the mouth to Sioux City, Iowa. Quarter-boats for the accommodation of the party were built at Leavenworth, Kans., and the work was carried that season as far as Boonville, Mo.

Congress, this winter, 1878–'9, changed the title of the appropriation to a "survey of the Missouri River from its mouth to Fort Benton, Montana," and made an additional appropriation of $30,000 with which, in April of the following year the field work was resumed, and reached Saint Louis toward the end of May, when the party was at once transferred to Sioux City, where new quarter-boats had been built in the meantime. The old quarter-boats, I believe, were turned over to the Mississippi River Commission.

Work was begun at Sioux City, June 6, and on the 6th of September following was connected with the point of beginning the previous year. Five hundred and eighty one miles were surveyed this year.

In 1880 another appropriation of $30,000 was made, but subsequently $5,000 of it was, by order of the Secretary of War, used for improvement work at Sioux City.

By probably some inadvertency the title of this appropriation was changed back to its former designation, namely, "Survey of the Missouri River from its mouth to Sioux City, Iowa." The appropriation, therefore, not being available for work above Sioux City, was used in carrying a line of carefully checked levels from Sioux City to the mouth, the levels carried along with the survey having been unchecked and necessarily done so hurriedly in order to keep pace with the other work as to throw doubt on their correctness. The subsequent levels have all been carefully checked.

In 1881 an appropriation of $30,000 for continuing the survey was made and the title corrected to read from the mouth to Fort Benton. The steamer Missouri was now purchased and fitted up for the service, it being impracticable to use quarter-boats above Sioux City. Funds were not available so that a party could be started for the field before August 26. On the 31st, work was begun at Fort Randall, Dak., and closed at Sioux City October 20. In 1882 Congress appropriated $40,000 for continuing the work, but it was not available until August 10. On the 26th of that month a party left Sioux City for Pierre, Dak., where field work was begun September 6 and closed at Fort Randall October 21.

No appropriation was made for the work in 1883, and the unexpended balance of the old appropriation not being adequate for the purpose nothing was done in the field that year.

The work done up to the year 1884 consisted of an accurate delineation of the shore-lines, islands, and sand-bars the general topographical features of the valley and the line of bluffs bordering the same, the whole checked by a system of triangulation carried along the river banks, the limited means and necessity for rapid progress not admitting of anything more permanent. Soundings were made on lines normal to the current and from 500 to 1,500 feet apart. Carefully checked levels also, as before mentioned, have been carried from Pierre to the mouth.

The whole has been platted on a scale of 1 inch to 1,000 feet, making 40 sheets 40 by 120 inches each. These have been reduced to a scale of 1 mile to 1 inch, photolithographed, and 1,000 copies printed.

The Missouri River Commission, having assumed control of the work in the fall of 1884, determined upon a secondary triangulation of the river to be carried from bluff to bluff, to be marked by permanent monuments; also to establish lines of permanent bench-marks, the whole to be connected with the former survey. The steamer Missouri, which had been out of the water at Sioux City since the close of work in the fall of 1882, was ordered to be put in such a state of repair that it could be used during the remainder of the season after being taken to Glasgow, Mo., where it had been decided to begin the work, an allotment from the general appropriation for improvement having been made for the purpose.

Orders for the repair of the steamer were received by me October 1. On examination it was found that a new knuckle all round, many new floor timbers and bottom planks were indispensable, as well as minor repairs. The boat also had to have new calking throughout. Repairs were finished, and the boat started down the river on the 31st of the month, and reached Glasgow on the 8th of November.

In the meantime parties had been organized, and work was begun on the 12th.

The triangulation work was in charge of Assistant O. B. Wheeler, while the building of the stations after their location by Mr. Wheeler, cutting out lines of sight, establishing permanent bench-marks, and connecting the same with both the triangulation and the former survey, and also transferring the levels from the old bench-marks to the permanent marks, was under my direction.

The work was continued until it reached Boonville on December 15, where, the weather having become quite cold, and fearing a sudden closing of the river, operations with the steamer were suspended, most of the party were discharged, and the

steamer started for Saint Louis to be laid up for the winter. It was, however, caught in the ice at Providence, 25 miles below Boonville, where it remained until March 12, when it was released and taken to Saint Louis, where it was placed on the ways for needed repairs, both to woodwork and boilers, preparatory to starting in the spring for Fort Benton, Mont., where it had been decided to commence a similar work to that done in the fall from Glasgow to Boonville.

Upon the close of work at Boonville, as before stated, a small party, consisting of two foremen, four laborers, and two men with teams, the whole in charge of an assistant, was organized to continue the building of △ stations, which was carried on during the winter and until the end of March, 1885, when, having made a connection with the Coast Survey at Tavern Rock, Mo., the building of △ stations was discontinued.

The monuments marking the triangulation points consisted of a stone 18 inches by 18 inches by 4 inches, with a small hole drilled in the center of one side; also marked with a △ and the letters "U. S.," all cut one-fourth inch deep into the stone. This was placed 3 feet 4 inches in the ground, and on the stone and centered over the hole in the middle was placed a piece of 4-inch gas-pipe, 3 feet long, the top covered with a cast-iron cap secured to the pipe by a bolt and nut. On the top of the cap were the words "Missouri River Commission," and in the center a triangular-shaped projection, one-fourth inch high, in the center of which a small hole was drilled. The lower edge of the cap came to the surface of the ground, care being taken in setting to keep the center of the cap exactly over the hole in the center of the stone.

The permanent bench-marks were the same as for the △ monuments, except that the pipes were 4 feet long and stood, when set, 1 foot out of the ground. The stones were marked "U. S. B. M.," and had a $\frac{1}{4}$-inch copper bolt leaded into the center, projecting one-fourth inch. The caps were marked "Missouri River Commission B. M.," and had a rounded projection in the center one-fourth inch high. The real bench-mark is the copper bolt in the stone, and when the bench is used the cap is taken off and the rod let down through the pipe on to the bolt. Levels, however, were taken on both bolt and cap.

The permanent-bench-marks were set on lines running across the valley, about 5 miles apart, and as nearly as practicable at right angles with the thread of the stream. On the portion done, the valley being from 2 to 3 miles wide, not more than three bench-marks were placed on a line, as a rule—one at the foot of the bluff on each side, and one between—care being taken in the selection of a location to provide against disturbance by the encroachments of the river.

Twenty-four permanent bench-marks were set and levels transferred to all but four. To these it was not practicable to carry the levels without delaying the main party. The levels were carefully run and checked by a level following the leading one, and as a rule repetitions were required when differences occurred on pegs or bench-marks of ten thousandths of a foot.

The lines of permanent bench-marks completed are numbered from 40 to 48, both inclusive, No. 40 crossing just below Boonville, and No. 48 at Cambridge, 5 miles above Glasgow.

These lines and numbers are part of a series of lines about 5 miles apart, and numbered from the mouth of the river upward.

The permanent bench-marks are designated thus, $\frac{48}{1}$, $\frac{48}{2}$, &c., $\frac{48}{1}$ being the first mark on line 48 on the right bank of the river, $\frac{48}{2}$ the next mark on the line, and so on.

One or more of the bench-marks in each line was connected with the new triangulation by a system of small triangles, a base line for the purpose being measured with a steel tape at some convenient point. Connection with the previous survey was generally made by a carefully-run stadia line. If the distance was too great, a system of triangulation was resorted to. Angles were read sufficient to determine the azimuth of the permanent bench-mark lines when the triangulation is reduced.

The repairs to the steamer Missouri were completed early in April last, and on the 13th of the month the steamer was started for Fort Benton, Mont., having on board 300 △ and B. M. stone, 800 △ and B. M. pipe, and an amount of subsistence stores estimated as sufficient for a party of 57 men for five months.

Only a single crew for the steamer, one assistant engineer, and assistant in charge were taken from Saint Louis, it having been arranged that the balance of the party should report at points above, principally at Bismarck, Dak.

It was soon found that the Missouri had not the power nor the construction to enable her to make more than very slow progress in such a river as the Missouri. Her machinery is light and required frequent repairs. It being necessary also for the purposes of survey to have sleeping accommodations for a large number, a great share of the boat is covered with a cabin which gives so much wind-surface that she is obliged often to lie by in a wind when an ordinary boat could have proceeded. These delays were frequent, especially through the months of April and May, during which we were obliged to tie up and stop on account of the wind alone on sixteen different days. We

reached Kansas City April 24, Omaha May 4, Sioux City May 12, Pierre May 25, and Bismarck June 1.

At Bismarck the Missouri was lightened by transferring about 15 tons of stone and pipe to the U. S. steamer Josephine, then at that place for repairs. Five hundred △ and B. M. stone, which had been sent from Saint Louis by rail, were also shipped by the Josephine and distributed at convenient points above.

Above Bismarck we had the June rise in the river to encounter, and the increased velocity of the current on that account made a resort to the tow-line almost a daily necessity. Sometimes the men pulling at the line could get us over the rapid places, but more frequently we were compelled to use the capstan.

On the 30th of June we had reached the Dauphin Rapid, about 95 miles below Fort Benton, and on the evening of July 4 arrived at Fort Benton.

As soon as the small quarter-boat for the use of the triangulation party, the materials for which were brought on the steamer from Saint Louis, can be completed, the work of the season will commence.

After leaving Pierre, Dak., two assistants were constantly employed making a sketch of the river from the roof of the steamer, taking bearings with a compass, and estimating distances. It has been completed on a scale of 1 inch to 1,600 feet, and traced on cloth, and will be of great use in mapping out work as the survey proceeds.

The distance, as shown by the sketch, from Pierre to Bismarck is 253 miles, and from Bismarck to Fort Benton 815 miles, making a total length of river yet to be surveyed 1,068 miles. This estimate of distance agrees very closely with several others, especially with a table prepared by the assistants on the work of improvement above Bismarck, which gives the distance from Bismarck to Fort Benton at 816, and with the estimate of 805 miles made in 1874 by Lieut. F. V. Greene, U. S. A.

Very respectfully, your obedient servant,

D. W. WELLMAN,
Assistant Engineer.

Lieut. W. L. FISK,
Corps of Engineers, U. S. A.,
Secretary Missouri River Commission.

APPENDIX B.

REPORT OF MAJOR CHARLES R. SUTER, CORPS OF ENGINEERS.

SAINT LOUIS, MO., *October* 5, 1885.

GENTLEMEN: I beg leave to submit for your information the following report on the work of improving Missouri River from Sioux City to its mouth, from the time the Commission assumed charge of the work to June 30, 1885, the end of the last fiscal year:

At the meeting of October 11, 1884, the Commission decided that it was inexpedient, owing to the lateness of the season, to begin work on this improvement before the spring of 1885. They, however, decided on the extent and general character of the work to be done this season, and allotted from the general appropriation $300,000 for work in the vicinity of Kansas City, Mo., and $105,000 for work near Saint Joseph, Mo. The former was to be the initiation of the general work of improvement of the river. As soon as these matters had been decided on, measures were taken to put all the plant belonging to the Commission in safe winter quarters, and the offices at Kansas City and Saint Joseph were closed, all operations being confined to watching and caring for the public property. The plant which had been used at Saint Joseph was left in the water, but that at Kansas City, being much exposed, was hauled out on top of the bank for safe-keeping.

The larger portion of the new plant, aggregating ninety-three boats and barges, was left at Bushberg, 25 miles below Saint Louis, in a good winter harbor. With this last division of the fleet a small force of mechanics were retained, in addition to the watchmen, and during the winter and spring they were employed in repairing and finishing the boats, manufacturing tools, &c.

All expenditures were made by the secretary of the Commission till January 21, 1885, on which date I was directed by the Secretary of War to take charge of the work. During the winter, plans were matured for the working organization and all arrangements made for beginning work as soon as the river was clear of ice. In the month of March I was enabled, through the courtesy of General Gillmore, president of the Mississippi River Commission, to secure the services of the tow-boats Etheridge and Osceola, belonging to the Mississippi River work. They arrived at Saint Louis April 2, and as soon as safe navigation on the Missouri was assured they, together

with our own tow-boat, William Stone, were assigned to the task of moving the new plant from Bushberg to Kansas City and Saint Joseph, distant, respectively, 432 and 531 miles. It was decided to leave at Bushberg eleven pile-sinkers, not likely to be needed this season, and to send up eighty-one boats and barges, besides all the skiffs and yawls on hand. The first tow left Bushberg April 12, and the three boats aggregated eighteen trips in all, the last two trips being made in July. At the end of June, 72 pieces had left Bushberg, viz: six hydraulic graders, five quarter-boats, six mattress-boats, four hydraulic pile-sinkers, forty-two barges 100 feet by 25 feet, and nine barges 64 feet by 16 feet. The two last tows comprised one machine boat and eight barges 100 feet by 25 feet. Besides this work the Etheridge was employed in bringing around from Jeffersonville, Ind., fifteen barges, 100 feet by 25 feet, which had been built for the work during the winter, and all three boats were employed in taking to Saint Joseph the plant assigned to that work and in miscellaneous towing. After all the plant had been moved, the Stone and Etheridge were assigned to the Kansas City work, and the Osceola to that at Saint Joseph.

The plant passed through the winter safely with the exception of some trifling damage to that at Saint Joseph.

In March field operations were begun at Kansas City and Saint Joseph, and will be described under those heads.

KANSAS CITY.

The office here was reopened March 11, Assistant S. H. Yonge having been assigned to the charge of the work. The boats were repaired and launched and arrangements made for supplying brush and stone. The former was procured by hired labor; the latter was furnished by the Kansas City, Saint Joseph and Council Bluffs Railroad. Only the old plant could be used, the new boats being too heavy for the small tugs used heretofore on the work. This occasioned much delay and increased the cost, but the necessity for immediate work was deemed imperative.

The work authorized by the Commission for this season contemplated the revetment of the left bank in Parkville and Kaw bends and the right bank in Quindaro Bend. Of these three, Parkville Bend was considered the least important and Kaw Bend the most so. Considerable work had been done here in former years, the last being in 1882. Subsequent to the completion of this last work the channel changed in the upper part of the bend and began a severe erosion of the bank, which at that point was unprotected. This erosion extended down-stream, taking in flank the upper portion of the work of 1882, and a considerable portion of it was destroyed. To check this erosion seemed the most pressing necessity, and accordingly, on April 17, work was begun at the head of the caving bank near the mouth of Line Creek. The revetment consisted of a woven willow mattress, strengthened by a rectangular system of wire cables extending from the top of the previously graded bank to a distance along the bed of the stream of about 90 feet from low-water mark, and covered above low-water mark with a layer of riprap. In order to save their track, the Kansas City, Saint Joseph and Council Bluffs Railroad had constructed a number of stone spur-dikes along this caving bank. These spurs had caused eddies to form, with the result of eroding the bank in pockets, making a very irregular shore-line. It being a matter of considerable difficulty to follow these short curves. they were usually disregarded, the stream edge of the mattress being kept on as uniform a line as possible, while its width was increased or diminished as the sinuosities of the shore-line rendered necessary. The average width of mattress was 133 feet, the thickness below the water-line being from 10 inches to 12 inches, and on the graded bank from 6 inches to 8 inches. Owing to the high stage of water the stone covering could only be placed on the upper portion. By the end of June a length of 3,000 feet of revetment had been constructed, leaving a gap of 5,500 feet still to be closed. It may be said in this connection that the work done in 1882 has not shown any sign of weakness as yet, and as this work, though similar in character, was not as substantial as that now being constructed, there is good reason for hoping that the work done this season will prove satisfactory. Experience has amply demonstrated that on the Missouri River the revetment must extend from the top of the bank to the limit of scour, and that the mattress must be securely tied to the bank as well as thoroughly loaded with stone. Above low-water mark a flat graded bank, with a substantial covering of stone resting on a thin mattress, offers the best protection against the action of ice and of waves. Detailed specifications of the type of revetment in use this season, both at Kansas City and Saint Joseph, are appended to this report (Appendix B 1). During the balance of the season work will progress much more rapidly, and it is probable that the revetment of Kaw and Quindaro bends will be completed.

On May 30, 1885, proposals were invited for furnishing 50,000 cubic yards riprap stone at Kansas City. Twelve bids were received and opened June 20, as per accompanying abstract.

Abstract of proposals opened by Maj. Charles R. Suter, Corps of Engineers, at Saint Louis, Mo., at 12 o'clock m., June 20, 1885, for furnishing and delivering on Government barges 50,000 cubic yards or more of riprap for improvement of Missouri River in the vicinity of Kansas City, Mo.

No.	Names and addresses of bidders	Landings where riprap is to be delivered.	Distance from limits of work. Number of miles up-stream.	Distance from limits of work. Number of miles down-stream.	Quantity, cubic yards.	Price per cubic yard.	Charge for towage per cubic yard.*	Comparative price per cubic yard.	Amount.	Remarks.
1	T. M. Hackett & Son, Atchison, Kans.	1 mile east of Atchison City, Kans	47	.....	50,000	$0 69½	$0 11¾	$0 81¼	$40,625	
		10 miles west from Kansas City, Mo	.....	.....	50,000	69½	.....	69½	34,750	Lowest bid.
		Between Kansas City, Mo., and Liberty Landing, 8 miles east of Kansas City, Mo.	.....	4	4,000	75	2	77	3,080	
2	Henry Hedderman and Luman Blackman, Topeka, Kans.	Parkville, about 6 miles above Kansas City, or at landing between Kansas City and Parkville.	.....	.....	50,000 or more.	85	.....	85	42,500	
3	James D. Burr, Topeka, Kans	½ mile below Parkville, Mo	.....	.....	50,000	1 20	.....	1 20	60,000	
4	John Arthur and Nicholas McAlpine, Wyandotte, Kans	Quindaro, Wyandotte County, Kans	.....	.....	50,000 or more.	1 00	.....	1 00	50,000	
5	Francis T. Mulholland, Kansas City, Mo.	Quindaro	.....	.....	50,000	1 39	.....	1 39	69,500	Informal. Only one bid received.
6	Alexander Graves, of Lexington, Mo., and Benjamin J. Franklin, Smith D. Woods, William F. Crowley, and John Donnelly, of Kansas City, Mo.	Parkville, Mo	.....	.....	50,000	93	.....	93	46,500	
		On west bank of Missouri River at Barker's Water Tanks, between Nearman and Pomeroy Stations, Missouri Pacific Railroad.	3	.....	50,000	89	0¾	89¾	44,875	
7	Henry McPherson, Boonville, Mo	Wayne City, Mo	.....	7	25,000	1 00	3½	1 03½	25,875	
		Blue Mills Landing	.....	17	25,000	1 25	8½	1 33½	33,875	
8	William Young, Pomeroy, Wyandotte County, Kans.	Pomeroy, Kans	5	.....	50,000	99	1¼	1 00¼	50,125	
9	E. A. Berry and S. S. Sharpe, Wyandotte, Kans.	Pomeroy, Kans	5	.....	50,000	1 17	1¼	1 18¼	59,125	
10	Edmund Saxton, Kansas City, Mo	Between a point 1 mile above Parkville and a point 1 mile below Randolph.	.....	.....	50,000	1 05	.....	1 05	52,500	

*The towage charge added for comparing proposals is at the rate of one-half of one cent per cubic yard per mile for towing up-stream, and one-quarter of one cent per cubic yard per mile for towing down-stream. Distance measured from Parkville, above, and Randolph, below, Kansas City.

Abstract of proposals opened by Maj. Charles R. Suter, Corps of Engineers, at Saint Louis, Mo., at 12 o'clock m., June 20, 1885, &c.—Continued.

No.	Names and addresses of bidders.	Landings where riprap is to be delivered.	Distance from limits of work. Number of miles up-stream.	Distance from limits of work. Number of miles down-stream.	Quantity, cubic yards.	Price per cubic yard.	Charge for towage per cubic yard.	Comparative price per cubic yard.	Amount.	Remarks.
11	W. B. Strang, jr., & Co., P. O. Box 2054, Kansas City.	Kansas City, Mo.	......	......	20,000	89	....	89	17,800	
		Quindaro, Kans.	.....	......	15,000	89	....	89	13,350	
		Independence	.....	....	15,000	95	....	..	14,250	Landings not specified.
12	G. T. Nelles, Leavenworth, Kans ...	Pomeroy, Kans.	5	......	50,000	70	1¼	71¼	35,625	

It has been recommended to the Chief of Engineers to accept the bid of T. M. Hackett & Son, of Atchison, Kans.

For further details see report of Assistant S. H. Yonge (Appendix B 2).

Money statement.

December 2, 1884, amount allotted by Commission		$300,000 00
Amount expended by secretary of Commission for purchase of fifteen barges	$20,048 04	
Amount expended by Major Suter to June 30, 1885	42,853 30	
Outstanding liabilities June 30, 1885	12,276 89	
		75,178 23
July 1, 1885, amount available		224,821 77

SAINT JOSEPH.

The office at this place was reopened on March 11, Assistant S. W. Fox being in charge of the work. As soon as the plant could be repaired and got ready for service, three breaks in the Elwood revetment which had developed in the neighborhood of the old stone dikes put in by the Saint Joseph Bridge Company were ordered to be closed; they aggregated 940 feet in length. Work began April 4 and ended April 17. The force was then transferred to Bon Ton Bend, and the revetment of the upper side of French Bottom was commenced on May 19. By May 30, 776 feet of mattress had been constructed at the head of the work and a junction effected with the revetment constructed by the Saint Joseph Water-Works Company. From this date till June 12 work was confined to the placing of rock on the revetment. At that date work was suspended, owing to the high stage of water. During the remainder of the season this revetment will be extended 10,000 feet, when the allotment for the work will be exhausted. A further extension of about 3,000 feet seems necessary, and the Elwood revetment should be extended up-stream about 18,000 feet, to the bluffs near Belmont, to secure the work already in from being flanked.

During the season brush and stone have been procured by hired labor and by purchase in open market.

On May 30, 1885, proposals were invited for furnishing 15,000 cubic yards riprap stone at Saint Joseph. Four bids were received and opened June 20, 1885, as per accompanying abstract:

Abstract of proposals opened by Maj. Charles R. Suter, Corps of Engineers, at Saint Louis, Mo., at 12 o'clock m., June 20, 1885, for furnishing and delivering on Government barges 15,000 cubic yards or more of riprap, for improvement of Missouri River in the vicinity of Saint Joseph, Mo.

No.	Names and addresses of bidders.	Landings where riprap is to be delivered.	Distance from Saint Joseph water-works: Up-stream.	Distance from Saint Joseph water-works: Down-stream.	Quantity, cubic yards.	Price per cubic yard.	Charge for towage per cubic yard.†	Comparative price per cubic yard.	Amount.
			Miles.	*Miles.*			*Cents.*		
*1	Andrew Sheridan of Saint Joseph, Mo.	Kansas shore, 1 mile above Saint Joseph water works	1	......	15,000	$1 15	½	$1 15½	$17,287 50
		One half mile north of Belmouth, Kans.	......	5	15,000	1 17	2½	1 19½	17,925 00
*2	Henry Hedderman and Luman Blackman Topeka Kans.	Belmont Landing, about 6 miles above Saint Joseph	......	5	‡15,000	95	2½	97½	14,625 00
*3	Thomas J Carter, Saint Joseph Buchanan County, Mo.	About 1½ miles above Saint Joseph water-works.	1½	.....	15,000	1 39	⅜	1 39⅜	20,906 25
*4	Henry W Dunn Saint Joseph, Mo.	About 1 mile above pumping station of the Saint Joseph water-works.	1	....	15,000	1 00	½	1 00½	16,037 50

* Recommended that all these bids be rejected.

† The towage charge added for comparing proposals is at the rate of one-half of 1 cent. per cubic yard per mile for towing up-stream, and one-fourth of 1 cent. per cubic yard per mile for towing down stream, distance measured from Saint Joseph water-works.

‡ Or more.

It has been recommended to the Chief of Engineers to reject all the bids.
For further details see report of Assistant S. W. Fox (Appendix B 3).

Money statement.

December 2, 1884, amount allotted by Commission		$105,000 00
Amount expended by secretary of Commission for purchase of fifteen barges	$7,016 80	
Amount expended by Major Suter to June 30, 1885	22,608 23	
Outstanding liabilities June 30, 1885	4,584 71	
		34,209 74
July 1, 1885, amount available		$70,790 26

Very respectfully, your obedient servant,

CHAS. R. SUTER,
Major of Engineers.

The MISSOURI RIVER COMMISSION.

B 1.

SPECIFICATIONS FOR MATTRESS WORK.

Grading.—The average height of bank is estimated to be 16 feet. It is proposed to grade the bank to a slope of 2½ to 1, excepting in localities where the irregularities of bank line and projecting points exposed to the movements of ice may make it necessary to grade to a slope of from 3 to 1 to 4 to 1.

It is estimated that the proportion of bank which should receive the flatter slopes will amount to 10 per cent. of the entire bank to be graded. On this basis the average quantity of earth to be removed per linear foot will amount to 13¼ cubic yards.

Brush mattress.—The class of mattress which it is proposed to use to consist of a continuous woven willow construction, extending from the top of the bank into the stream 90 feet beyond ordinary low water, to have a thickness of 6 inches from the top of the bank to mid-stage, and 12 inches from mid-stage to the stream edge.

According to this specification the total width of mat for a 16-foot bank, graded to a 2½ slope, will be 136.8 feet, requiring 125.1 cubic feet of brush; for a slope of 3½ to 1 the total width will be 148.2 feet, requiring 133.6 cubic feet of brush.

The average width of mattress for all slopes will be 137.9 feet, requiring 126 cubic feet, or about one cord per linear foot.

To construct the extensive works herein contemplated, an immense quantity of brush will be required, and as it is probable that it will often be impossible to procure brush of average size and quality, some deviation in the thickness of mat as given above will become necessary, especially when large and scraggy brush has to be used, in which event it will be necessary to weave a thicker mat on account of the large meshes resulting from the use of this class of material.

Wire-rope or rod-chain system.—For giving additional strength to the woven mattress and for anchoring it to the bank it is proposed to use either a system of galvanized steel wire ropes or chains made of iron rods in lengths of about 10 feet, or of such other lengths as circumstances may require, the system to consist of longitudinal and transverse members.

Longitudinal members to consist of ten continuous wire ropes or iron chains spaced 10 feet, laid in the direction of the stream and woven into the mat, the principal or outer member to be a ¾ steel rope or a rod-chain made of ⅞ square iron; the inner members to be ⅝-inch steel ropes or ⅝ square bars. Transverse members to consist of principals placed at intervals of 90 feet, consisting of ¾ steel ropes or ⅞ square rods, the intermediates to be ⅝ rods or ropes spaced 15 feet.

The transverse members to be laid at right angles to the longitudinals, the two intersecting members to be held together at each point of intersection by clevises or open links. The stream end of each transverse member to be made fast to the principal longitudinal by a clevis or stirrup, and the shore end to a suitable anchorage, set back from the edge of the bank, by a ring-bolt.

In view of the fact that the efficiency of the iron chains and timber deadmen would become more quickly impaired by the action of the elements than the submerged portion of the mattress, it is recommended in case iron-rod chains should be adopted instead of wire ropes that some method of protecting the iron from rapid oxidation should be used, provided an efficient process can be employed without adding materially to the cost of the work. The Bar-Bower process of coating iron is suggested as

account of its simplicity. However, should it be found impracticable to use this method, a coating of coal-tar applied to the iron when heated may accomplish the desired purpose.

It is also recommended that the timber used for deadmen be subjected to some wood-preserving process, or that rough blocks of rock be substituted for the timber.

Rock work.—The mattress on the graded bank to be covered with 3,000 pounds of broken rock per linear foot for the 2½ slope and 3,700 pounds for the steeper slopes, or an average of 3,070 pounds per linear foot for all slopes, which it is estimated will be equivalent to a thickness of 9 inches.

The low-water mat to be weighted with about 1,350 pounds of rock per linear foot, making the total quantity of rock required per linear foot 4,420 pounds, or 2 cubic yards of about 2,240 pounds.

It will be desirable to fill the interstices of the bank mattress lying between the elevation of 2 feet below ordinary low water and that of mid-stage with macadam or gravel, and on top of this to place the covering of rock of larger size.

The estimated quantity of macadam required is one-fourth cubic yard per linear foot. The cost of one set of plant, with a capacity for making 80 cubic yards of macadam per day, is $1,500 complete.

B 2.

REPORT OF MR. SAMUEL H. YONGE, ASSISTANT ENGINEER.

KANSAS CITY, MO., *July* 10, 1885.

MAJOR: I have the honor to submit my report on the work of improving Missouri River in the vicinity of Kansas City, Mo., for the fiscal year ending June 30, 1885, as follows viz:

CARE OF AND REPAIRS TO PLANT.

As there was no suitable and safe place in the vicinity of Kansas City, Mo., where all the boats belonging to the work could be laid up together for the winter I submitted, about the latter part of October, 1884, a plan for constructing a system of ways and tracks to be used for taking the boats out of the river and placing them on the bank above the stage of ordinary high water. This plan receiving your approval, steps were immediately taken to carry it into effect. As some of the details of this work are novel and original, a brief description is given.

There were constructed ten inclined ways, tied together in pairs, five tilting frames, all supported on piles driven to a solid bearing, a set of ten horizontal tracks, a second set of five tracks, and three cross-tracks with a sliding frame. The ways were placed at right angles to the general direction of the bank, and extended to a sufficient depth into the river to permit boats being floated on them at the lowest stage of water. The timber used in the construction of the ways and of the tilting frames was oak exclusively. The angle of inclination of the ways was about 13¼°, great pains being taken in their construction to place all of them in the same plane.

The tracks were 6 inches by 6 inches pine drift bolted to 8-inch posts driven 4 to 6 feet into the ground, and extended back about 300 feet from the top of the bank. They were used not only in sliding the boats into position after being drawn up the ways, but also served the purpose of blocking in keeping them above ground.

For transferring the boats from the ways to the tracks, and for changing their position from an inclined to a horizontal one, tilting frames were used, which in their inclined position would connect closely with the different pairs of ways, and when horizontal, with the tracks. Each frame revolved on an oak timber, the upper half of which was accurately rounded to serve as an axle, blocks with a semi-intrado to match the axle being placed on the under side of the tilting-frame timbers. The sizes of the timbers and the details of their arrangement are shown in the accompanying drawings.

For the purpose of carrying the boats to the tracks that were not directly connected with the tilting-frames the set of cross-tracks carrying the sliding frame on which the boats were placed in moving them was used. The details of this frame are shown in the drawing. The elevation of the cross-tracks was fixed so that the upper surface of the sliding frame would be on a level with that of the main tracks.

The power used for hauling the boats up the ways and out on the tracks was applied by means of timber capstans, with 10-inch drums and 10½-foot levers, to each of which a team was attached. Four capstans were used in hauling the boats up the ways and two for pulling them back on the track. In pulling out the heavier boats there was used in addition a set of double and treble blocks, the lines from which were

carried to the capstans. The lines were attached to the boats, in the case of the two hydraulic graders and the two iron steam-launches, by means of slings passed around their hulls; in the case of the lighter boats by means of iron hooks.

The lines from the boats to the capstans passed over pulleys in movable frames, which were so placed on the bank that the direction of the pull was approximately parallel to the ways until about one-half the width of the boat rested on the tilting-frames; the pulley-frames were then removed and the boat drawn over on the tilting-frames until the overhang of the shore side of the boat exceeded that of the river side sufficiently to overcome the axle-friction and cause the frames to revolve. The boats varied in size from 15 feet by 60 feet, weighing about 16¼ tons, to 24 feet by 100 feet, weighing, with the machinery, about 100 tons. The weight of the iron steamers was estimated at about 55 tons each.

The work of hauling out the boats was begun on December 14, 1884, about which time very cold weather set in. The river was closed by ice on December 17. This proved a serious obstacle to getting the boats out rapidly, on account of their freezing in and their bottoms being coated with a heavy layer of ice, which could not be removed before pulling them out, and also on account of the accumulation of slush ice around the foot of the ways after each boat was taken out.

On account of the intense cold the difficulties of proceeding with the work finally became so great that it had to be suspended temporarily on January 3, 1885, although but one-half of it had been accomplished. It was resumed on February 2, 1885, and completed on February 6, 1885, the ice surrounding the boats and ways, amounting to about 800 tons, having been cut out and removed during the latter part of January. Thirty-two boats in all were taken out of the river and laid on the tracks.

The whole arrangement worked satisfactorily and without the occurrence of an accident. The ways were used again in the spring for launching the boats after their being repaired. The repairs to boats, which were commenced about the middle of March, 1885, consisted in calking and pitching the seams of all the wooden hulls; scraping, repairing, and painting the hulls of two iron steamers, "Melusina" and "Sabrina"; making necessary repairs to the machinery of the graders and steamers, fitting up a quarter-boat for temporary use in field work, and fitting up a barge to be used as a mattress-boat during spring operations. This work was completed early in May and the boats all launched.

As the Kansas City, Saint Joseph and Council Bluffs Railroad Company gave notice that the grounds which during the preceding two years had been occupied by the buildings used for quarters and storage had to be vacated, it became necessary to remove these buildings to a new site. This was done in September, 1884. Besides the buildings moved there were erected several frame buildings for storing plant, &c. During the month of June, 1885, the work of erecting quarters on four barges for the brush-gangs to be employed this summer and fall was begun. Some repairs were also made to the quarter-boats, graders, and pile-sinkers brought from Bushberg, Mo.

The plant from Bushberg began to arrive on April 21, 1885, and up to July 1 there were received six hydraulic graders, four pile-sinkers, six mattress-barges, five quarter-boats, twenty-five 100-foot barges, and seven 64-foot barges.

SURVEYS AND PROJECTS.

Surveys of the Missouri River in the vicinities of Fort Leavenworth, Kans., Kansas City, Mo., and Lexington, Mo., were made during the month of July 1884. On these surveys the projects submitted to you under date of July 31, 1884, for improving the Missouri River in these localities, and the estimates of cost for the works proposed therein were based.

During the month of October, 1884, a survey of the river between Kansas City, Mo., and Randolph Bluffs, Mo., was made to determine the extent and cost of the works necessary to hold the river in its position at that time, in the East Bottoms, immediately below this city. On account of my time being occupied by other pressing duties, the project for this work was not submitted until December 31, 1884. In February, 1885, a new project was submitted for the improvement of the reach of the river extending from Quindaro, Kans., to Randolph Bluffs, Mo. A part of the work proposed in this project was constructed this spring. A description of the work done is given below. During the latter part of the past month a resurvey of the river from Parkville, Mo., to Randolph Bluffs, Mo., was made. From this survey it appears that since the fall of 1884 erosion has taken place in the different parts of the reach, as follows, viz:

In Parkville Bend.—The length of bank eroded is 4,300 feet, with an average width of about 31 feet.

In Quindaro Bend.—The length of bank eroded is 10,000 feet, with an average width of 47 feet.

In the upper part of Kaw Bend.—The length of bank eroded is 5,165 feet, with an average width of 135 feet extending from the lower end of the dikes constructed by

SKETCHES OF

S, TILTING FRAMES, TRACKS. ETC.

USED IN HAULING BOATS OUT OF RIVER

AT

KAW BEND.

—— SCALES ——

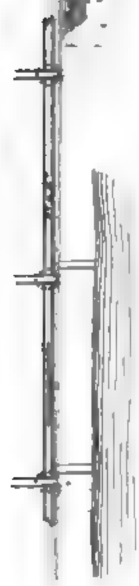
GENERAL DRAWING .... FEET.

DETAILS " " ....

TO ACCOMPANY REPORT OF

S. H. YONGE, ASST. ENGR.

DATED JULY 10, 1885.



the Kansas City, Saint Joseph and Council Bluffs Railroad Company to the present head of the revetment of 1882.

In the extreme lower part of Kaw Bend.—The total length of bank erosion is 2,800 feet, with an average width of 44 feet. Along the Harlem front the erosion is slight. The length of the bank eroded is 2,800 feet, with an average width of 18 feet.

In the East Bottoms, below Kansas City, Mo.—The length of the bank eroded is 5,830 feet, with an average width of 40 feet. Most of this erosion occurred in February and March, 1885. An attempt was made by the owners of the adjacent lands to protect this bank during the summer and fall of 1883 by constructing four rock spurs, without, however, protecting the adjoining banks between the spurs from the eddies. When the survey of October, 1884, was made, it was found that in consequence of this omission one of these dikes had been severed from the bank by the erosion of the latter and had sunk out of sight. Since that time the other three have also been flanked and are now in the channel of the river. As a large volume of water now flows between them and the bank, they have aided in the destruction which they were intended to prevent, by forcing the current against the bank.

CONSTRUCTION MATERIALS.

Soon after my arrival at Kansas City, about the middle of March, 1885, an effort was made to arrange for the purchase of rock and brush, to be delivered at the site of the proposed works, in open market. This failed, however, on account of the high prices demanded by the parties offering to furnish these materials. Subsequently an arrangement was made with the Kansas City, Saint Joseph, and Council Bluffs Railroad Company to furnish rock at the rate of $7 per car, delivered at the head of the work. This company also constructed a side-track for the delivery of rock and brush at the work.

Three thousand five hundred and forty-six cubic yards of rock were furnished by the railroad company, the cost of which, delivered at the work, was 63.4 cents per cubic yard.

No satisfactory arrangements could be made for purchasing the brush required for the work, and steps were taken early in April to procure it by hired labor. About 1,200 cords were procured in the neighborhood of Harlem, Mo., and other points near the work. Of this quantity 1,000 cords were transported to the work in upper Kaw Bend by railroad and 200 cords by barges.

One thousand five hundred and twenty-seven cords were brought from Cow Island and Iatan Bar, a distance of about 45 miles by river, of which there were transported to the work 100 cords by railroad and 1,287 cords by barges, towed by the steamer "Melusina," and 140 cords by barges, towed by the tow-boats "Osceola" and "Etheridge." The barges used for transporting the brush from Cow Island and Iatan Bar were towed to these points by the tow-boats "Osceola" and "Etheridge," the steam launch "Melusina" being used to tow the barges loaded with brush down-stream to the work.

The average cost of brush per cord, inclusive of the price paid for it on the stump, the cost of transportation by teams, steamboats, and railroad, labor, subsistence, &c., was $1.9404 per cord. With a view to determining the quantity of brush available for the purposes of the works proposed for the summer and fall operations, and to securing its purchase where desirable, a careful examination of all the brush patches between Atchison, Kans., and Camden, Mo., has been instituted.

CONSTRUCTION OF REVETMENT.

Although the spring of the year is not a favorable season for carrying on works on the Missouri River on account of the high stage of water usually prevailing at that time, and other unfavorable conditions, it was decided to proceed with the construction of revetment in the upper part of Kaw Bend for the following reasons, viz: The length of bank in the upper part of Kaw Bend, above the revetment of 1882, still to be protected in April, 1885, was 8,560 feet. The erosion in this locality, referred to in former reports, has been and is still going on, and threatens to reach the revetment of 1882 and cause the river to flank and destroy a portion of it.

It was expected by the work constructed this spring: (1) To materially reduce this danger; (2) to render it better possible to complete the revetment in the upper part of the bend, and to connect it with the revetment of 1882, before any very extensive damage had been done to this revetment, than would have been the case if the construction of all of it had been postponed until after the June rise; (3) to prevent such changes in the upper part of Kaw Bend as would probably have resulted in diverting the main flow of the river from the lower part of the bend, thereby producing an unstable regimen of the river in that locality, and making the permanent improvement of the river in this vicinity extremely difficult and expensive.

The erosion mentioned above had been going on for over two years, and the Kansas City, Saint Joseph and Council Bluffs Railroad Company, the safety of whose road-bed has been endangered by it, has during the past year attempted to avert this danger by constructing a number of rock-spur dikes along the shore from 100 to 400 feet apart. One effect of these dikes was to create the usual eddies above and below them, which hastened the cutting of the bank immediately adjacent, and seriously impeded the rapid progress of the mattress work.

The difficulties of the work were further increased by the fact that during the time of construction the bank was exposed to the force of the current, which was intensified by the winds prevailing at that season, having a full sweep in the direction of the current for several miles.

This made the sinking of the mat especially difficult, as on account of its pliability, with the strong current quartering against it, it had a tendency to roll up while being sunk. This occurred twice toward the close of the work, the latter time resulting in a section of mattress about 1,000 square feet in area being torn out. This accident was probably caused chiefly by a quantity of drift, which, by the force of the wind and current combined, was lodged under and on top of the mattress before being sunk. The damage was repaired by weaving a new section of mattress and sinking it so as to cover the break. On account of the high stage of water prevailing at the time, the height of bank graded was only from 7 to 12 feet. The slope given was 1 to 2¼, except at the dikes, which were trimmed down to a very flat slope before being covered with the mattress, and the banks in the bays between the dikes, to which a slope of 1 to 2 was given.

From the time work commenced until May 6 the hydraulic grader formerly used at Saint Charles, Mo., with a pump 10 inches by 16 inches, was used. After this date a hydraulic pile-sinker with a pump 7 inches by 16 inches was used. The pumps on both boats were single cylinder Davidson, and did excellent service. The smaller pump answered the purpose sufficiently well, as the quantity of earth to be moved per foot of bank was comparatively small, but its capacity would have been too small had the bank height been much greater.

The total quantity of earth moved was 12,400 cubic yards. The average cost of grading per cubic yard, including all expenses, was 3.8 cents. This cost is high and furnishes no criterion for future work, as neither of the pumps could be worked continuously and consequently to the best advantage, frequent stoppages being caused by the necessity of removing the rootlets and other pine drift which clogged the strainers of the pump-wells, and which were brought there by the eddies caused by the dikes; and also that of removing the rock in trimming down the dikes before grading could proceed.

In constructing the revetment the Sioux City woven mattress, strengthened by a system of galvanized steel wire-ropes, was used. This system consisted of one ¾-inch rope laid along the outer or stream edge of the mattress, six ⅝-inch ropes being placed at intervals of 15 feet between the stream cable and the shore. These longitudinal ropes, which were paid out from reels placed on the mattress-boat, were, as far as practicable, woven into the mattress and connected with each other by transverse steel wire-ropes spaced 15 feet apart. These latter ropes were ⅜ inch in diameter, except every sixth one, which was ⅝-inch in diameter.

To anchor the mattress to the bank the transverse ropes were securely attached to the stream cable by stirrup bolts and the shore ends to pieces of rock, weighing in the case of the ⅜-inch ropes about 250 pounds, and in that of the ⅝-inch rope about 350 pounds, and being set in the former case 3 feet, and in the latter 5 feet, beneath the surface of the ground on top of the bank.

At the points where the transverse crossed the longitudinal ropes the latter were pulled up through the mat and the transverse ropes passed through the loops thus formed, the two sets of ropes then being fastened together by wire.

The boat used in the construction of the mattress was similar to that used here in 1882 and 1883, differing therefrom only in being larger, its dimensions being 4 feet by 16 feet by 96 feet.

The mattress had a thickness of from 10 inches to 14 inches, except the portion on the slope bank, which had a thickness of from 6 inches to 8 inches.

At those points where, through the eddy action before referred to, the bank had been eroded between the dikes, it had been intended to drive lines of piling between the heads of the dikes across the bays in order to avoid the necessity of increasing the width of the mattress, but this was found impracticable on account of the obstructions met with below the bed of the river in the form of loose rock, which had been thrown there by the railroad company during the past year in constructing their dikes. It therefore became necessary to increase the width of the mat at such points by from 50 to 60 feet. The greatest width of mattress was 180 feet.

The total length of mat constructed was about 3,000 feet, with an average width of 133 feet, making a total area of about 400,000 square feet. The average area of mat

woven per man per day for the whole work was about 480 square feet. The total quantity of brush used was 2,680 cords, or $\frac{87}{100}$ cord per 100 square feet.

All the mattress above the water-surface, amounting to 73,500 square feet, was covered with broken rock, leaving about 60,000 square feet still to be covered after the high water subsides.

The net cost of the revetment, exclusive of care of plant, repairs to plant, new plant purchased, and surveys, is $5.00346 per linear foot.

To complete the work by covering all of the bank mattress above low water with rock will, it is estimated, require an expenditure of $1,650, making the total net cost per linear foot $5.55346.

I have been ably assisted by Mr. R. H. Bacot in the field work, and by Mr. E. F. Hermans in the office.

Very respectfully, your obedient servant,

SAMUEL H. YONGE,
Assistant Engineer in charge.

Maj. CHAS. R. SUTER,
Corps of Engineers, U. S. A., President Missouri River Commission.

B 3.

REPORT OF MR. S. WATERS FOX, ASSISTANT ENGINEER.

SAINT JOSEPH, MO., *July* 11, 1885.

MAJOR: I have the honor to submit herewith a report of the operations under my charge during the fiscal year ended June 30, 1885.

In accordance with your instructions I prepared and submitted to you, July 31, 1884, a project with estimates in detail of work on the Saint Joseph Division deemed necessary to make the reaches considered reasonably permanent in the absence of a general improvement of the river.

Accompanying that report were two maps, one of the Saint Joseph Reach, and the other of the Atchison Reach, both compiled from surveys of 1882 and July, 1884.

The force was then reduced to the minimum necessary for the regular duties in the office, the care of plant and reading of gauges. The maps, records, and all papers on file pertaining to the improvement works in the vicinity of Glasgow, Mo., and Saint Charles, Mo., and the survey of Missouri River from Boonville to Lexington, made in the fall of 1882, were completed, indexed, and transferred to the Saint Louis office for final filing.

In October the gauge at Nebraska City was repaired at a cost of $100. The usual shore-line surveys and cross-sections were made in the vicinity of that gauge and at White Cloud and Saint Joseph. A line of levels was run to each gauge, and corrections in elevation of zero made when necessary.

The fleet at Elwood was made up anew, all of the barges thoroughly cleaned out, and a number of them calked preparatory for the winter season. In November inspections of gauges and the prescribed surveys in their vicinities were made at Waverly, De Witt, Glasgow, Boonville, Jefferson City, and Saint Charles.

On receipt of Special Order No. 1, the office at Saint Joseph was closed. The fleet was left in charge of three watchmen. I reported for duty at Saint Louis on the 18th of November, and was assigned the charge of collecting and compiling the physical data that had been taken from time to time at points on the Missouri River from its mouth to Sioux City. The work was begun at once and continued under my direction until March 9, when I was relieved by Mr. James A. Seddon. March 9 I left Saint Louis under instructions to proceed to Saint Joseph and prepare for the expenditure, in accordance with my project of February 21, 1885, of the allotment of $105,000, made for the improvement of the river in that vicinity.

An office was opened March 11. The loss of and damage to United States engineer property incident to the break up and movement of ice in the Missouri River March 9 was reported in detail in my letter of March 14. The burning, on the 28th of March, of the Buchanan County court-house, in which our office was located, was reported on that date. The loss of United States engineer property thereby was reported in item on the property return for the first quarter, 1885.

The first work contemplated in the project was the repairs to the Elwood Revetment. Weaving mattress was begun April 4 and finished on the 17th, 940 linear feet, or 95,050 square feet, having been woven in three pieces, as follows, viz: At the upper break, 560 linear feet; at the middle break, 72 linear feet; at the lower break, 308 linear feet; 926.16 cubic yards of rock were placed on the mattress, when work there was suspended until after the June rise.

The total cost of the work in that condition was $3,402.26, or $3.61 per linear foot. An additional expense of 90 cents per foot will be incurred in the delivery and placing of 675 cubic yards of rock further required; thus the total cost of the revetment complete would be $4.51 per linear foot.

The other work contemplated in the project was the construction of revetment in Bonton Bend. Weaving mattress was begun May 19 and suspended May 30, 775.8 linear feet, or 84,546.2 square feet, having been woven in one piece, the upper end resting at the head of the revetment constructed in 1882, the lower end lapping the revetment constructed by the Saint Joseph Water Company in the fall of 1884. The placing of rock on the mattress was finished June 12; 1,350.4 cubic yards in all were used.

The total cost of the revetment complete was $3,100.92, or $3.99 per linear foot.

The method of construction of both works was in general accordance with the specifications contained in my project of July 31, 1884.

The brush and rock for this work were procured by hired labor.

Repairs to plant were made as required. Work was suspended June 12.

It is proposed to resume the construction of revetment in Bonton Bend during the current month.

I am, major, with great respect, your obedient servant,

S. WATERS FOX,
Assistant Engineer.

Maj. CHARLES R. SUTER,
Corps of Engineers, U. S. A.,
President Missouri River Commission.

APPENDIX C.

REPORT OF CAPTAIN JAMES B. QUINN, CORPS OF ENGINEERS.

SAINT PAUL, MINN., *August* 10, 1885.

MAJOR: I have the honor to transmit herewith report of operations for improving Missouri River from Sioux City, Iowa, to Fort Benton, Mont., for the fiscal year ending June 30, 1885.

Very respectfully, your obedient servant,

JAMES B. QUINN,
Captain of Engineers.

Maj. CHARLES R. SUTER, U. S. A.,
President Missouri River Commission.

IMPROVEMENT OF THE MISSOURI RIVER FROM SIOUX CITY, IOWA, TO FORT BENTON, MONTANA TERRITORY.

By act of Congress approved July 5, 1884, the direction of the improvement of the Missouri River was vested in a Commission. This act necessarily caused an immediate suspension of all active operations upon the river until the Commission could be organized and a policy for the improvement of the river determined upon. As it was believed that this delay would be of short duration, the repairs to plant under way were carried to a conclusion, and affairs maintained in such a condition as to permit of an immediate resumption of active work as soon as circumstances would permit.

THE STEAMER EMILY.

The small steamer Emily, belonging to the work, was thoroughly overhauled and provided with compound engines of an improved kind. These engines were of the Wolff type, the high-pressure cylinder being 12 inches in diameter and the low-pressure cylinder 24 inches, the stroke of each being 42 inches. The low-pressure cylinder exhausted into the stack; no vacuum-pump or condenser was employed.

No change was made in the boiler. A cut-off mechanism was provided for the high-pressure cylinder, but as it was found that more steam was generated by the boiler than could be used when it was in gear, it was disconnected, and the steam followed in the high-pressure cylinder during full stroke, as it did also in the low pressure.

The results of the first trial trip compared with a similar trip with the old high-pressure engines are as follows, viz:

Items.	1883.	1884.
Distance run .... miles..	14	14
Average speed per hour .... do...	5.56	10.23
Fuel per hour .... cords..	0.849	0.481
Fuel per mile .... do...	0.192	0.06

The boat handled admirably well, and altogether the trial was exceedingly satisfactory; in fact, the results were believed to be entirely too flattering, and an opportunity to make a comparative test over a longer distance was awaited with impatience. This opportunity occurred late in the fall. Word was received at the office that the watchman in charge of the Government property at Gallatin Rapids, Montana Territory, had been obliged to abandon his post and seek safety from the depredations of a band of horse thieves and assassins who had banded together under the name of "regulators" and were scouring the banks of the Missouri River, hanging or driving off all those who were not members of the gang or who, unsuspicious of personal danger, were seeking to earn an honest livelihood by hard work in isolated places.

Although it was quite late in the season, it was resolved to send the Emily to Gallatin Rapids to bring down to Bismarck, for temporary safety, such stores as it would not be prudent to leave unguarded at Gallatin; furthermore, it was believed that the services of the Emily would be required in the vicinity of Bismarck in the spring, and that she might safely winter there.

The river between Sioux City, Iowa, and Pierre, Dak., had recently been surveyed and the distance between the two points ascertained to be 372 miles. In 1881 the Emily steamed over this course, when the stage of water was 4 feet higher than when the trip was made in 1884. In both cases the course was against the current.

Items.	1881.	1884.
Distance .... miles..	372	372
Speed per hour .... do...	3.618	4.762
Fuel per hour .... cords..	0.926	0.680
Fuel per mile .... do...	0.27	0.144

It is safe to say that the new engines effected a saving of fully one-half the fuel previously required to make this trip, since, owing to the low stage of water, in 1884 the steamer was aground and sparring 11 hours 56 minutes, during which time fuel was being used, and which, not being deducted, increased the amount consumed per mile. In 1881 the steamer was aground and sparring but 35 minutes, and the deeper water was otherwise very much in her favor.

Although the engines of the Emily were far from perfect, they, without doubt, proved the economy and applicability of compound engines for the propulsion of Upper Missouri River boats. It is a matter of regret that the life of this steamer was not prolonged for another season, as I am confident that much better results both as regards speed and economy in the use of fuel were within the range of possible attainment.

LOSS OF THE EMILY.

Although the Emily returned to Bismarck several days after the usual close of navigation, the river was still open, and she was taken to a point about 7 miles above the Bismarck Bridge, as secure a place for wintering as it was believed possible to find in the vicinity of Bismarck. She had hardly arrived at this place when the ice closed in around her, and after the usual winter preparations she was left in charge of a watchman, with the positive assurance by experienced steamboat men that she was perfectly safe. Under ordinary circumstances she probably was so, but most unexpectedly there came, on the last of November, a previously unheard-of rise, and broke up the ice in the river, which forced the Emily out on to the bank, where she froze fast before she could be freed from surrounding ice and launched. Several other boats which were wintering on the opposite side of the river came very near meeting the same fate, but were saved by a providential wind which blew off-shore. The severity of the winter prevented anything being done for the rescue of the steamer before March, when a force was set to work to free her from the ice and place her in the water. The ice was cut from around her as much as possible, and as the water had again begun to rise, jack-screws were applied to free her from the frozen bank. She yielded suddenly to the strain, but carried off so much earth adhering to her bottom

that she was gradually dragged down and sunk in about 12 feet depth of water. All efforts to raise her proved unavailing, and, with the exception of such articles of general outfit as could be rescued, she is a total loss.

IMPROVEMENT OF THE "ROCKY" RIVER.

The project for the improvement of the portion of the Missouri River from Sioux City, Iowa, to Fort Benton, Mont., having been submitted for the consideration of the Commission, so much of it as referred to the improvement of the rocky portion was approved and the necessary allotments of the funds available for the work were made December 2, 1884.

Steps were immediately taken to carry out the designs of the Commission. After considerable correspondence an agreement regarding the delivery of machinery for a first-class dredge, containing such features of construction as the character of the work upon which it was to be employed necessitated, was concluded with the Osgood Dredge Company, Albany, N. Y., January 8, 1885. The machinery was to be delivered at Bismarck Landing, Dakota, free on board, for $15,304. This machinery was to leave Albany, N. Y., in time to permit it to reach Bismarck by April 1. The contract for the construction of the hull and cabin for this dredge was awarded to Chapman & Lynch the 10th of March. Free transportation for the materials and labor from Bismarck to Fort Benton was to be provided by the United States, and the dredge, hull, and cabin were to be completed in one month after the landing of the materials. Upon the completion of the hull and cabin, &c., the contractors were to receive $7,500, less such sum as might be forfeited through failure to deliver in time, &c.

February 16, 1885, a contract was made with Chapman & Lynch to furnish afloat at Bismarck Landing, as soon after the ice left the river as was practicable, five barges at $999.25 each, and one quarter-boat for $2,575.

February 10, 1885, the purchase of the steamer Josephine to serve as a snag boat was agreed upon, the owners to make such repairs and additions as were required to fit the boat for the service desired, and to deliver her afloat with steam up and in good running order at Bismarck Landing as soon as the condition of the navigation in the spring would permit, for $13,200.

Numerous other contracts were made for the delivery of supplies, tools, &c., to be delivered at Bismarck, Dak., as soon as navigation opened.

DEPARTURE FOR FIELD OF OPERATIONS.

In anticipation of the breaking up of the ice a crew for the Josephine and a small working force were started for Bismarck, where they arrived April 5. I arrived at Bismarck myself April 6, during the afternoon of which day the final break up of the ice took place. As the winter had been very severe, and the ice in the river was unusually heavy, I anticipated the usual gorging and flooding of the banks, but the ice moved out quietly and no damage was done. As soon as the railroad officials were assured that there was no danger from the gorging of the ice, they commenced to move down to the landing the train-loads of freight which had been held in the upper yards for security. The working-force was at once put to work unloading the cars.

On the 8th of April the steamer Josephine arrived at the landing, and after a short trial trip of a couple of miles down the river and back, to assure myself that the machinery and appurtenances were all in good order, the boat was accepted, and the loading of the machinery, lumber, and supplies upon it was at once proceeded with. Shortly after the river was free from ice the new quarter-boat and barges were safely launched.

Four of the barges were left at Bismarck, and but one, loaded with machinery, and the quarter-boat, loaded with lumber, were taken in tow by the Josephine on the first trip up.

Although the weather was very stormy, and several delays, caused by furious snow-storms and gales of wind, occurred, the steamer arrived safely at its destination. It is estimated that 1,000,000 pounds of freight were transported by the Josephine on this trip, which, if shipped by other conveyances at the usual rate of $1.60 per 100 pounds, would have cost the Government in the vicinity of $16,000. From this it would certainly appear that the purchase of the Josephine was a profitable speculation. But this bit of sunshine was not altogether without its shadows, for in the return trip, and almost at the end of the journey, the wheel-shaft suddenly broke, and the vessel came very near being wrecked. The cost of repairs to machinery, in consequence of this mishap, amounted to $1,400, and the vessel was rendered useless for a whole month.

DAM-BUILDING.

The dam-building party was landed at Two Calf Island the last of April, and put to work getting brush and other materials, it being the intention to repair the dikes at

Grand Island as soon as the stage of water would permit. By the end of June quite a large amount of material had been collected, but the water was still too high to permit work upon the dam to be commenced before the end of July.

SNAGGING OPERATIONS.

Owing to the failure of the last river and harbor bill, no funds were available for carrying on this work this season. There are a great many snags at present obstructing the channel, and their removal is of pressing necessity. It is hoped that next season will witness a commencement of this important work, since the boat with which to do it is already on hand.

RECOMMENDATIONS.

As soon as the ice goes out of the river in the spring it would be advisable to commence the removal of snags at Sioux City and continue the work up the river until the time of high water, when the boat might proceed to Bismarck and take up such supplies and working-parties as would be needed in the upper portion of the river. For this work, next season, there will be required the sum of $22,000.

Although it will hardly be possible to do much with the dredge this season it should not be allowed to stand idle next season. To keep it in operation during the season will require the sum of $20,000.

In connection with the dredge there will be required a dam-building party to close chutes and protect the cuttings made by the dredge, and to dispose of the material removed from the channel by the dredge at places where it cannot be dropped out of the way. To provide for this party not less than $15,000 will be required.

The services of a small tow-boat will be required for the efficient service of the dredge and the dam-building party. This need not be very large, but something after the plan of a powerful launch. Such a boat should be delivered at Bismarck Landing for $6,500, and might be operated for the season for $5,000, or a total for launch and expenses of $11,500.

For incidental expenses, such as the office expenses and inspection of district officer, repairs to plant, miscellaneous tools and appliances, surveys of localities under improvement, &c., there will be required the sum of $15,000.

SUMMARY STATEMENT.

Snagging operations	$22,000
Dredging	20,000
Dam building	15,000
Steam tug or launch	6,500
Towing expenses	5,000
Incidental expenses	15,000
Total	$83,500

IMPROVEMENT OF THE "SANDY" RIVER.

As no work upon the sandy portion of the river has been attempted since my project for the improvement of this portion was submitted for the consideration of the Commission last December, the situation is without change. If my project meets with approval at least $160,000 might be expended upon this part of the river, making the grand total for the whole section of the river from Sioux City, Iowa, to Fort Benton, Montana, $243,500.

CONCLUSION.

It will be observed that upon this section of the Missouri River all the work done under the direction of the Commission is of a preparatory character, but it is hoped that with the aid of a dredge and the parties at work on the dams a very sensible improvement of the Rocky River will have been effected before the close of navigation. The permanent improvement of this portion of the river is, I think, entirely feasible with a very moderate outlay. As this is the portion that at present presents the greatest obstacles to navigation, it should very properly receive the earliest attention. As to the remainder of the river, it is safe to assert that the removal of the snags from the bends and deep-water channels would be of very great assistance, and is, at present, the most pressing requirement.

But while the further betterment of the channel will admit of slight delay, it is well to bear in mind the fact that as the country develops the river commerce will increase, and a better channel will become a necessity. At present the country

through which the river flows is sparsely settled. No important private enterprises occupy its banks, and such rectification of channel as might be necessary can be now carried out without encroaching upon valuable preserves. The brush and timber now available for such work will shortly be in the possession of private parties, who would exact from the Government its full value, and, in consequence, feasible works of improvement to day may for financial reasons be impossible in the future. Now is, therefore, the most advantageous time to commence and put the channel in good order in advance of the necessities of commerce, and thereby present a real encouragement to its advancement, instead of procrastinating till the character of the commerce is such as to demand that the improvement be made, and thus perverting the sensible view of such works, and making commerce an encouragement for improvements of water-ways.

Already the character of the commerce upon the Upper Missouri is assuming a feature that points to its permanent increase. The down-river freight is almost equal to that carried up stream, and bids fair to exceed it in a short time. The cereals raised in the Upper Missouri River Valley are the finest in the world, and the mineral resources are apparently inexhaustible. Coal and iron ore of the finest quality, in but short distances from superior water-power advantages, await the enterprise of some one to start the mills and factories for the supply of all the country bordering the Missouri. The superior quality of the grasses growing upon the uplands bordering the river valleys has already drawn immense herds of cattle to it, and the sheep industry, which is but in its infancy, already ships down the river over 1,000,000 pounds of wool a year. It needs but a casual glance to convince one that the possibilities of this region have not yet been even guessed at; that it must in time become populous, and maintain all those industries in a flourishing condition which appertain to civilization; that the wild and wayward Missouri must in time yield to persistent but gentle treatment, and develop into a deep and commodious avenue, wherein the commerce of this country shall pass securely and economically.

Money statement.

December 2, 1884, amount allotted by Commission		$99,000 00
Amount expended to June 30, 1885	$55,041 79	
Outstanding liabilities (estimated) June 30, 1885	9,928 74	
		64,970 53
July 1, 1885, amount available		$34,029 47
Amount that can be profitably expended in fiscal year ending June 30, 1887		$243,500 00

FINANCIAL STATEMENT TO JUNE 30, 1885.

Appropriation for Missouri River Commission, acts of August 2, 1882, and July 5, 1884; appropriation for improving Missouri River from Sioux City, Iowa, to Fort Benton, Mont.

Object.	Disbursements Upper Missouri district.			
	Allotment for office, &c., inspection expenses of district officer.	Allotment for work below Fort Benton, Mont.	Allotment for purchase and repair of plant.	Total.
Amount allotted	$8,500 00	$30,000 00	$60,500 00	$99,000 00
Expended to June 30, 1885	2,371 69	7,326 79	45,343 31	55,041 79
Unpaid liabilities (estimated)	343 39	2,500 00	7,085 35	9,928 74
Total	2,715 08	9,826 79	52,428 66	64,970 53
Balance available June 30, 1885	5,784 92	20,173 21	8,071 34	34,029 47
Total amount available				34,029 47
Amount that can be profitably expended in fiscal year ending June 30, 1887				243,500 00

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